



## ecology and environment, inc.

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International Specialists in the Environment

February 1, 1991

Mr. Steven W. Sturgess  
Missouri Department of Natural Resources  
205 Jefferson Street  
Jefferson City, Missouri 65102

RE: Draft Final Report for the North U Drive Remedial Investigation/  
Feasibility Study (RI/FS), Project Reference: MG2018

Dear Mr. Sturgess:

Ecology and Environment, Inc. (E & E) is pleased to present herewith the draft Final Report for the Phase 1 North U Drive Remedial Investigation/Feasibility Study. Five copies of this document are included. Per your instructions, we are forwarding one copy directly to Mr. David Crawford, U.S. Environmental Protection Agency Region VII for his review.

If you have any questions or comments on the enclosed report, please feel free to contact me.

Sincerely,

ECOLOGY AND ENVIRONMENT, INC.

John C. Parks, P.E.  
Project Manager

JCP:pjk  
Enclosure

cc: David Crawford, USEPA/Region VII



DRAFT FINAL REPORT FOR THE PHASE 1  
NORTH U DRIVE  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
SPRINGFIELD, MISSOURI  
VOLUME ONE

February 1991

Prepared for:

MISSOURI DEPARTMENT OF NATURAL RESOURCES  
WASTE MANAGEMENT PROGRAM (WMP)

Prepared By:

ECOLOGY AND ENVIRONMENT, INC.  
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## EXECUTIVE SUMMARY

The Missouri Department of Natural Resources (MDNR) contracted with Ecology and Environment, Inc., (E & E) to conduct a Remediation Investigation and Feasibility Study (RI/FS) at the North U Drive site near Springfield Missouri. This study was funded by the Federal Hazardous Waste Remedial Fund (Superfund) through a cooperative agreement between the State of Missouri and the U.S. Environmental Protection Agency (EPA).

The primary focus of this report is the presentation of new information gained through soil, soil-gas, and groundwater sampling and surface geophysical investigations. These activities were performed during the months of October and November, 1990. Data derived from the field investigation and sampling will be considered in conjunction with historical information, to guide subsequent activities at this site. Specifically, the objectives of Phase 1 were:

- 1) to identify the chemicals present and the affected environmental media;
- 2) to identify apparent sources of this contamination; and
- 3) to predict contaminant migration pathways.

The North U Drive site (Figure ES-1) is located east of Missouri Highway 13, about 1.25 miles north of Springfield, in Section 3, Township 29 North, Range 22 West, Greene County, Missouri. Presently, the site proper (hereafter referred to as the "study area") is bounded on the north by North Stage Coach Road, by Pea Ridge Creek to the east, by New Missouri Highway 13 to the west, and the south property line of

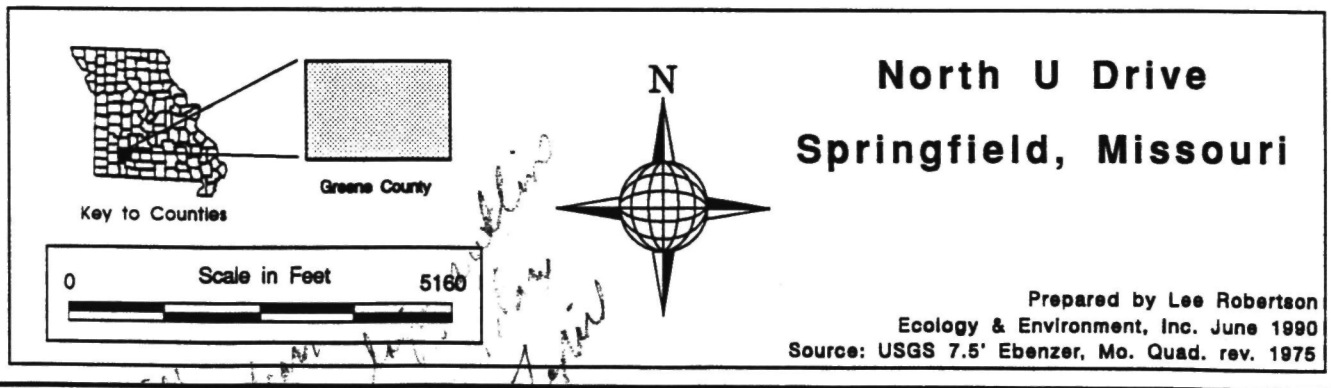
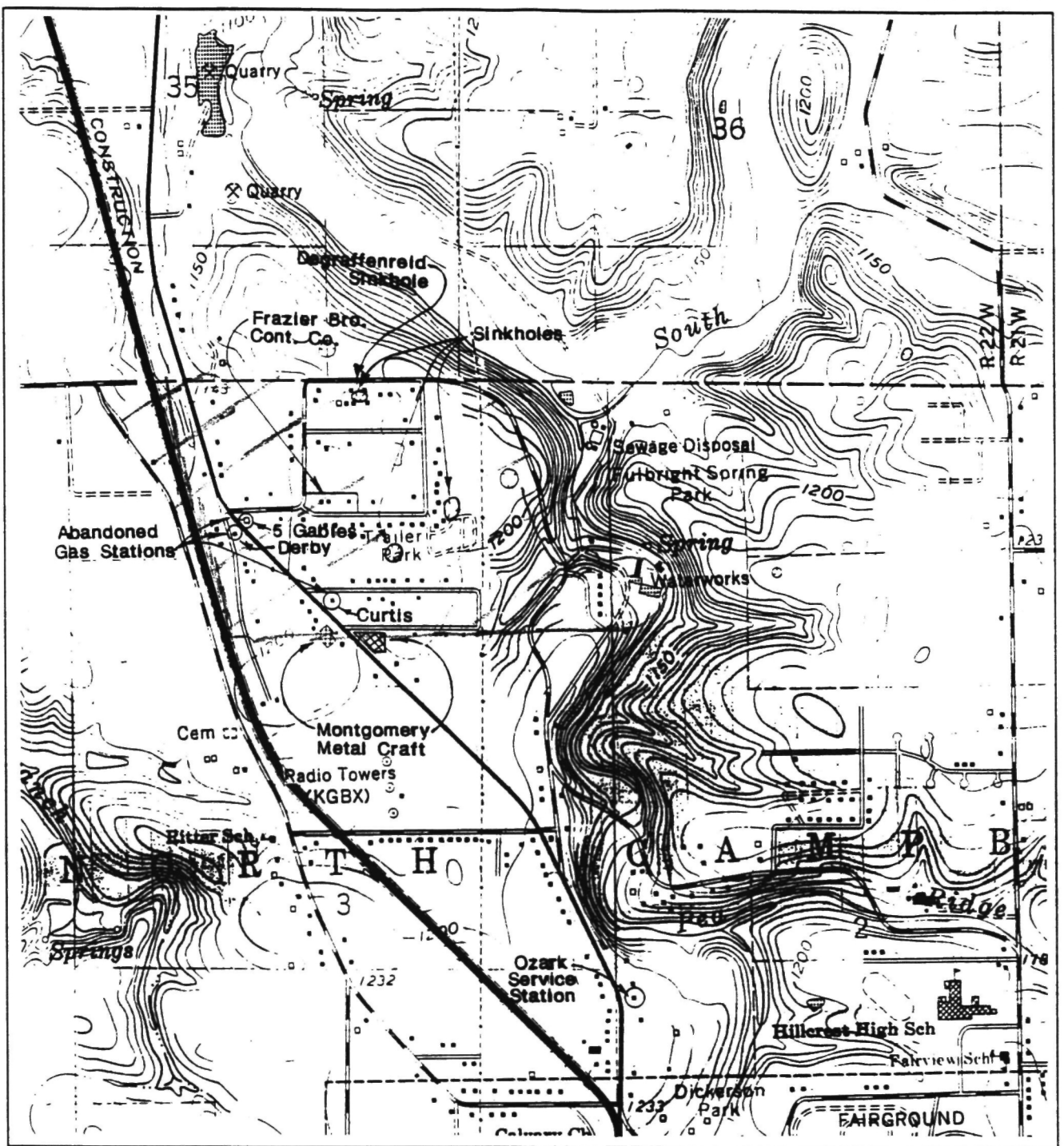


Figure ES-1: SITE LOCATION MAP

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 bordered  
 of site  
 suggest  
 of site  
 62-2

Montgomery Metal Craft to the south. These boundaries have been somewhat arbitrarily identified based upon preliminary information regarding potential contaminant sources, significant targets of contamination, and the estimated extent of contamination. These boundaries are subject to change as the investigation progresses.

The study area and its surroundings consist of rural/residential neighborhoods, farmland, woodlands and some commercial activity. The former Fulbright landfill (also a Superfund site) and the Fulbright Pump Station, a critical element of Springfield's water supply system, are located near the boundaries of the study area.

North U Drive was first identified as a potentially hazardous waste site in October 1983, when citizens complained of a chemical taste and odor in their drinking water. Affected residents consistently described a petroleum or gasoline-type odor in their wells.

MDNR initiated an investigation of well contamination in the North U Drive area in November 1983. Between this time and 1985, sampling investigations consistently identified several volatile organic compounds in the groundwater. The compounds detected most frequently and in the greatest concentrations are benzene, toluene, ethylbenzene and methyl tertiary butyl ether (MTBE), an anti-knock compound commonly found in gasoline.

The Missouri Department of Health and the Springfield-Greene County Health Department issued health advisories, in April and December of 1984, warning against the use of contaminated water for drinking, cooking and bathing.

Water lines were installed in the summer and fall of 1985 to provide Springfield city water to all residences affected, or potentially effected, by the groundwater contamination. In addition, a total of 68 wells within the study area were plugged, under the direction of the EPA and MDNR, to help control the spread of contamination.

The objectives of the investigation described in this report were:

- 1) to further characterize the extent of contamination, with respect to the types of contaminants present and the affected media (soil and groundwater);

*Handwritten notes:*  
A. Remond  
was completed  
under EPA  
Superfund program  
Consisting of 1) to further characterize the extent of contamination, with respect to the types of contaminants present and the affected media (soil and groundwater);

- 2) to determine the likeliest sources of subsurface contamination; and
- 3) to predict the directions in which the contamination might be expected to spread.

A combination of soil, soil-gas, and groundwater sampling was implemented to help achieve objectives 1 and 2. A review of historical information, and the completion of several geophysical surveys aided in achieving all three objectives.

At the outset of this investigation, nine properties were identified as being potential sources of the groundwater contamination within the study area. Following is a brief synopsis of each potential source:

- NFA* o **Former Five Gables Service Station.** This former service station, now the Bolivar Road Newsstand, is located at the intersection of Stage Coach Drive and Old Highway 13, on the southeast corner. The service station was closed some years ago at which time the above-ground storage tanks were removed. In 1976 a fire erupted at this service station while a tanker was refilling one of the storage tanks. It is not known whether any significant volume of unburned fuel was released to the environment during this incident. *what does RI data indicate?*
- NFA* o **Former Derby Service Station.** This former service station is located directly across the highway (on the west side of Highway 13) from the former Five Gables service station. It is unknown whether underground tanks were ever removed or even used at this station. All structures on the property have been razed, and the lot is vacant except one vent pipe remains indicating that at least one buried tank may still be present.
- pps* o **Former Curtis Service Station.** Located at the intersection of Old Highway 13 and North U Drive, this site is vacant with no surface structures remaining. The first complaints of "bad water" came from residences along North U Drive adjacent to this property. It is unknown whether underground tanks exist or existed here, but a significant quantity of a "petroleum-like" product was identified in a well on this property during earlier state investigations.
- pps* o **Montgomery Metal Craft (MMC) Plant.** This facility is located on Old Highway 13, immediately southwest of the former Curtis Service Station. MMC has been in business at least 30 years and has specialized in cleaning, refurbishing and re-coating used storage tanks. Until recently,

used tanks were cleaned and re-coated outdoors, along the south side of the facility. There is no evidence, from either employee interviews or site files, that any containment was ever used to collect materials derived from the cleaning process (sludges and cleaning solvents) or the asphalt overspray (containing "cutting" solvents) derived from the re-coating procedures.

- o **MMC Tank Yard.** This area, also belonging to Montgomery Metal Craft is located at the intersection of Old Highway 13 and South U Drive, on the southeast corner. The tank yard, which is partially fenced and entirely unpaved, is used to store new and used storage tanks. Other items on the property include service station fuel dispensers, a drum storage pad (diked), and a tank pad (also diked) containing two diesel fuel tanks.  
PPS
- o **Frazier Brothers Construction Company (FBCC).** This facility is located at the intersection of Stage Coach Drive and Parrish Drive, on the northeast corner. The FBCC is an electrical contractor that has been operating at this location for more than 10 years. According to FBCC personnel, no underground storage tanks have ever been installed at this site. A garage exists for routine servicing of vehicles.  
LAW
- o **Mobile Gardens Trailer Park (Sinkhole).** This sinkhole is located behind (south of) several residences along Parrish Drive. Historically, this sinkhole was used as a dump for wastes generated by trailer court operations, mostly construction debris. The sinkhole has been filled to existing grade with 25 to 30 feet of debris.  
LAW
- o **Degraffenreid Sinkhole.** This sinkhole is adjacent to the east edge of an auto repair garage located on North Stage Coach Drive. The garage has with a floor drain which releases into the open environment and directly into the sinkhole. For approximately 23 years diesel oil was released into the drain with lesser quantities of anti-freeze, various solvents and possibly other fluids related to auto maintenance.  
NFA
- o **Coble Sinkhole.** The center of this sinkhole is located behind (east of) the residence at 4044 Northwood Road. Behind this residence is the center portion of a sinkhole. No disposal activities were documented to have occurred on this property. Drainage from the south derives from the east end of the trailer park, where several abandoned underground septic tanks (and possibly some butane or propane tanks) may be located. Drainage from the north originates from the neighboring Cook residence, where at least 10 vehicles are stored on an open, unpaved lot.  
LAW

Aside from the source investigation, six open residential wells in the study area were sampled to obtain up-to-date information regarding the levels and physical extent of groundwater contamination. The analytical scope of these samples was expanded to include volatile organics, semi-volatile organics, metals, pesticides, and cyanide. Under previous investigations, well samples were analyzed for volatiles only.

Based upon all of the information obtained during Phase 1, these nine properties were more accurately classified according to their weight as potential sources of groundwater contamination:

- 1) **No Further Action.** The Degraffenreid sinkhole, the former Derby service station and the former Five Gables service station were all dismissed as highly unlikely sources of the volatile organics contamination associated with this study. Although suspect circumstances may prompt separate investigations at the Degraffenreid and Derby properties, no further action at any of these sites is recommended for Phase 2 of this investigation.
- 2) **Limited Additional Work.** Although not the likeliest potential sources, conditions at the Frazier Brothers Construction Company, the Coble sinkhole, and the Mobile Gardens Trailer Park sinkhole justify limited additional work under Phase 2 of this investigation. Relatively substantial organic contamination within the shallow subsurface at these properties justifies deeper soil sampling to help confirm whether this contamination is possibly contributing to the ground water pollution.
- 3) **Primary Potential Sources.** A combination of field data obtained during Phase 1, and historical data reviewed prior to the field activities, indicate that the Montgomery Metal Craft (MMC) Plant, the MMC tank yard, and the former Curtis service station are the likeliest potential sources of groundwater contamination. Additional subsurface sampling will be necessary to confirm attribution.

#### Identification of Chemical Present

Soil gas and soil sample analysis indicate the original primary contaminants, benzene, toluene, ethylbenzene, and xylene, remain of concern. While other contaminants were detected, these are most likely either confined near the surface (and associated with surface spills), or simply secondary compounds associated with the BTEX contamination.

*above MCL*  
*10x MCL?*

Results of the well samples show that no significant groundwater contamination has spread as far north as Parrish Drive. No significant concentrations of any compounds were identified in the samples. (One well did contain some contamination that appears to be related to a leaking septic tank.)

#### Preliminary Contaminant Migration Pathway

It can be interpreted from the Phase 1 investigation that the extent of contaminant migration has not changed drastically since previous studies. However, by eliminating some of the previous potential source areas, the conceptual geological model explaining migration from the remaining primary potential sources can be enhanced.

The following is a list of key elements which can be used to formulate a more comprehensive migration model and would be utilized to develop the Phase 2 Work Plan:

- o Groundwater contamination most likely originated in the vicinity of North U and South U Drives, on either side of Old Missouri Highway 13;
- o Groundwater contamination may be a combination of infiltration of past surface spillage at the Montgomery Metal Craft properties, and leakage/spillage near or into the well at the former Curtis service station (additional work is recommended at these sites);
- o Sinkhole development in and around the study area has evolved in an orientation parallel to the regional joint/fracture pattern (that is northeast/southwest and northwest/southeast directions);
- o While a more direct route of contamination to the groundwater exists at the sinkholes, soil gas and soil samples indicate these are not the likely routes by which the contaminants entered the subsurface;
- o Upon reaching the groundwater, contaminants from the three primary potential source areas would migrate along northeast and northwest trending joint patterns;

*what about sinkholes - diff patterns?*  
*& flow from all flow?*  
*7*

- o Contamination has not occurred downgradient from the inferred plume (the boundaries of this plume were estimated prior to Phase 1 sampling);
- o Limited water level information indicates that flow within the shallow aquifer is to the northeast, at least within the northern half of the study area;
- o Hydrogeologic data obtained during Phase 1 indicates that water levels in the deep aquifer, beneath the study area, have dropped significantly in recent years. Vertical migration of contaminants may have been extended as a result of this phenomenon; *Do we have wells screened deep enough to determine?*
- o Contaminant migration may be facilitated or impeded by deeper structural features within or near the study area.

It is anticipated that actual contaminant attribution to the groundwater can be defined by implementing further work at each site. Further characterization, regarding the extent of contamination, will depend upon a hydrogeologic study that should include monitoring wells, completed in both the shallow and deep aquifers, pump or slug tests, and dye tracing. Utilizing the geophysical and limited hydrogeologic information obtained during Phase 1, and the historical information obtained prior to Phase 1 field activities, well locations can be chosen to intercept the most likely migration routes leading from the general area of the suspected sources.

## 1. INTRODUCTION

This document serves as the Final Report for Phase 1 of the Remedial Investigation (RI) of the North U Drive site. The North U Drive site was proposed for placement on the National Priorities List (NPL) in October 1984. In June 1986, the listing became final. According to the Hazard Ranking System (HRS) the site scored 28.90 based on an observed release of benzene to the deep aquifer which serves the City of Springfield and 26 private wells (total population 133,215). The site was ranked 832 on the NPL in March 1989 and 1,048 as of August 1990. The Remedial Investigation and Feasibility Study (RI/FS) for this site is funded by the federal Hazardous Waste Remedial Fund (Superfund) through a cooperative agreement between the State of Missouri and the U.S. Environmental Protection Agency (EPA). The Missouri Department of Natural Resources (MDNR), the state agency responsible for the study, contracted Ecology and Environment, Inc., (E & E) to perform the RI/FS.

The format for this report was developed from a suggested format outline in the "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988).

### 1.1 REPORT OBJECTIVES

This report is intended to serve as the final report for activities conducted during Phase 1 of the RI investigation of North U Drive. As such, the report is intended to be a "stand-alone" document, and may, therefore, contain material already incorporated into other documents, such as the Work Plan, prepared prior to the Phase 1 field activities.

During the field activities it was determined that some of the background information obtained for the preparation of previous docu-

ments was outdated; the final report has been modified accordingly.

The primary focus of this report is the presentation of new information gained through soil, soil-gas, and groundwater sampling and surface geophysical investigations. These activities were performed during the months of October and November, 1990. Data derived from investigation and sampling, in conjunction with historical information, will be used to guide subsequent activities at this site. Specifically, the objectives of Phase 1 were:

- 1) to identify the chemicals present and the affected environmental media,
- 2) to identify apparent sources of this contamination, and
- 3) to predict contaminant migration pathways.

Information gathered during Phase 1 should satisfy these objectives in a manner such that the planning and implementation of Phase 2 activities, and ultimately the Feasibility Study, may be performed most prudently and efficiently.

## 1.2 SITE BACKGROUND

This section contains information pertaining to the cultural setting, physiography and history of the North U Drive site. Most of the background information in this section was obtained from site files belonging to the Missouri Department of Natural Resources (MDNR) Waste Management Program (WMP); the MDNR Regional Office in Springfield, Missouri; the Springfield-Greene County Health Department; the Springfield City Utilities; and the EPA Region VII office in Kansas City, Kansas. Additional information was gathered during interviews with local residents, though much of this information was speculative. Information directly related to the objectives of this investigation, and corroborated by other interviews or previous documentation has been included here.

### **1.2.1 Site Location and Description**

The North U Drive site is located east of Missouri Highway 13, about 1.25 miles north of Springfield, in Section 3, Township 29 North, Range 22 West, Greene County, Missouri. Figure 1.2-1 shows the general area, as well as potential sources within the study area. Groundwater contamination has been found in wells in a residential area, and in a small trailer park on the west side of the site.

Approximately 200 to 300 people live within 1/4 mile of the site. Land use within 1/4 mile of the site is primarily rural/residential, with some wooded and pasture lands. Businesses nearby include a tank repair and fabrication company, and a construction company. Several abandoned gasoline service stations are also in the vicinity. An overflow reservoir for the City of Springfield's municipal water supply is located approximately 1200 feet east of the known extent of contamination. In addition, Fulbright Spring and a city drinking-water well are just east of the lake. This water system serves more than 130,000 people in Springfield and Greene County.

### **1.2.2 Site History**

North U Drive was first identified as a potentially hazardous waste site in October 1983, when citizens complained of a chemical taste and odor in their drinking water. However, hydrocarbon-based contaminants were first discovered in private wells west of North U Drive as early as the mid-1960's. Subsequent action at this site did not begin until two local disposal facilities, the Fulbright and the Sac River landfills, drew attention in the early 1980's. At that time, several potential sources were identified in the immediate neighborhood of North U Drive. Each of these potential sites were considered more likely to be a source of the North U groundwater contamination than either of the two landfills. This was due to the proximity of each site to the contaminated wells, and also because of the type of contaminants present. Affected residents consistently described a petroleum or gasoline-type odor in their wells. Accordingly, several abandoned gasoline stations and at least two operating businesses known to handle solvents and petroleum-

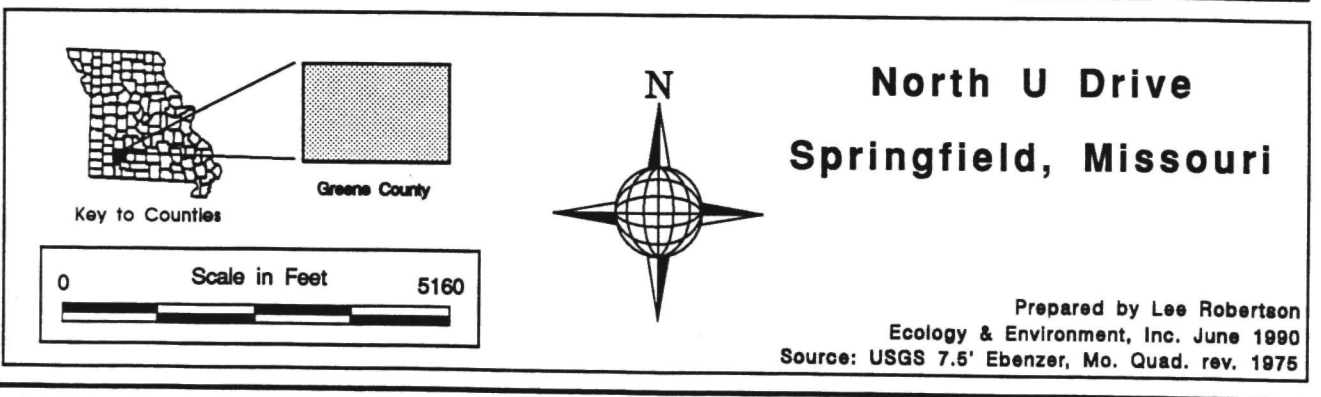
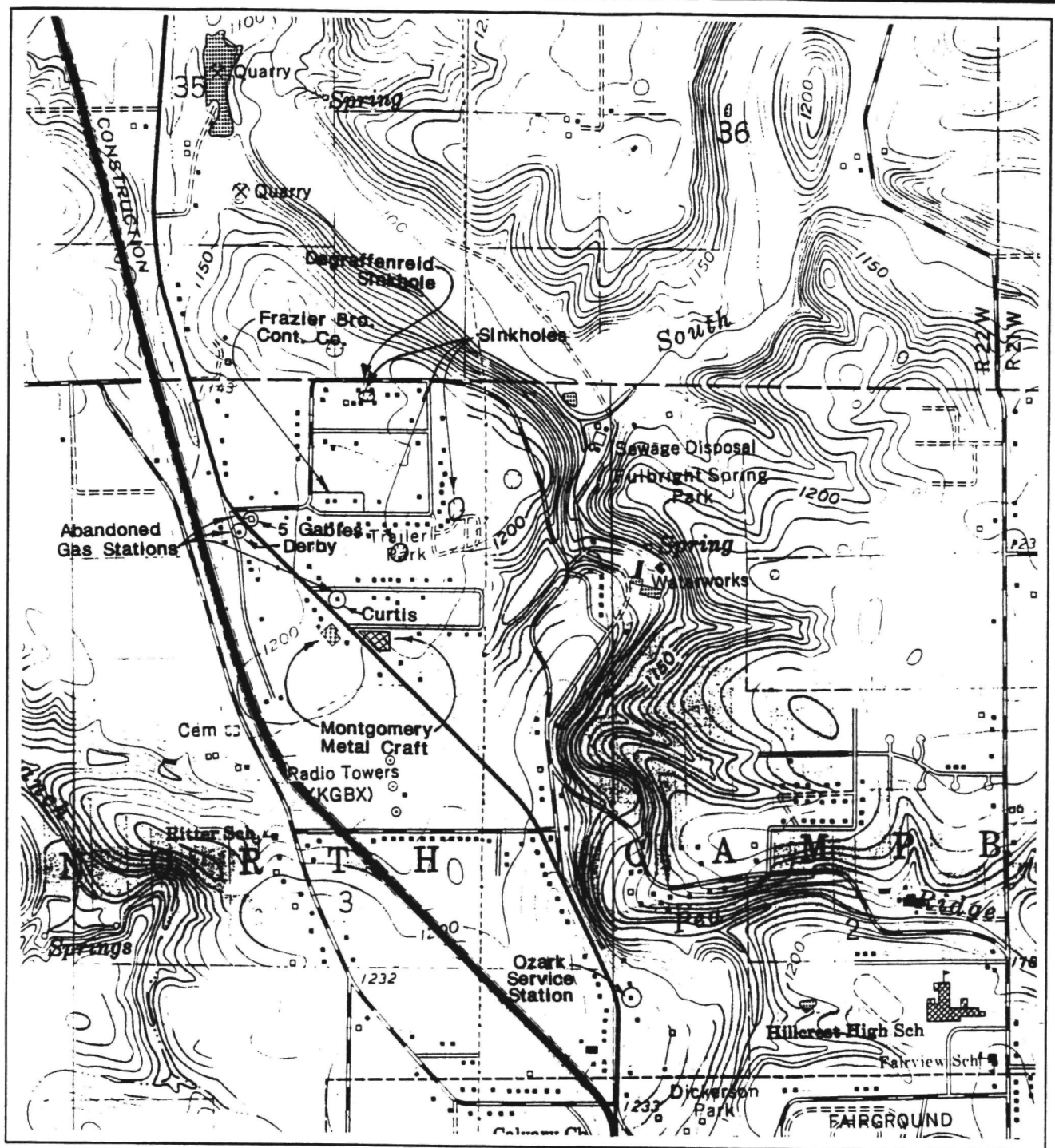


Figure 1.2-1: SITE LOCATION MAP

based compounds were considered the most likely potential sources of contamination. Three additional potential sources, all local sinkholes where dumping may have occurred, were also considered for this investigation. It should be noted that the inferred "contaminant plume", as defined by the groundwater sampling performed prior to Phase 1 of this RI, was completely surrounded by the potential sources mentioned above. It was, therefore, thought to be unlikely (even in a Karst terrain) that the contamination had migrated from some place outside of this "circle" of suspect properties. Figure 1.2-2 illustrates the general layout of the North U Drive neighborhood and identifies all potential sources, along with the inferred contaminant plume as established prior to Phase 1 field activities. A brief history of each potential source is presented below:

- o **Former Five Gables Service Station.** This former service station, now the Bolivar Road Newstand, is located at the intersection of Stage Coach Drive and Old Highway 13, on the southeast corner. According to Mrs. Helen Jones, the property owner, the service station was closed some years ago (exact date unknown), at which time the above-ground storage tanks were removed. She also claimed that there had never been buried gasoline tanks on the property. However, in 1976 a fire erupted at this service station while a tanker was refilling one of the storage tanks. It is not known whether any significant volume of unburned fuel was released to the environment during this incident.

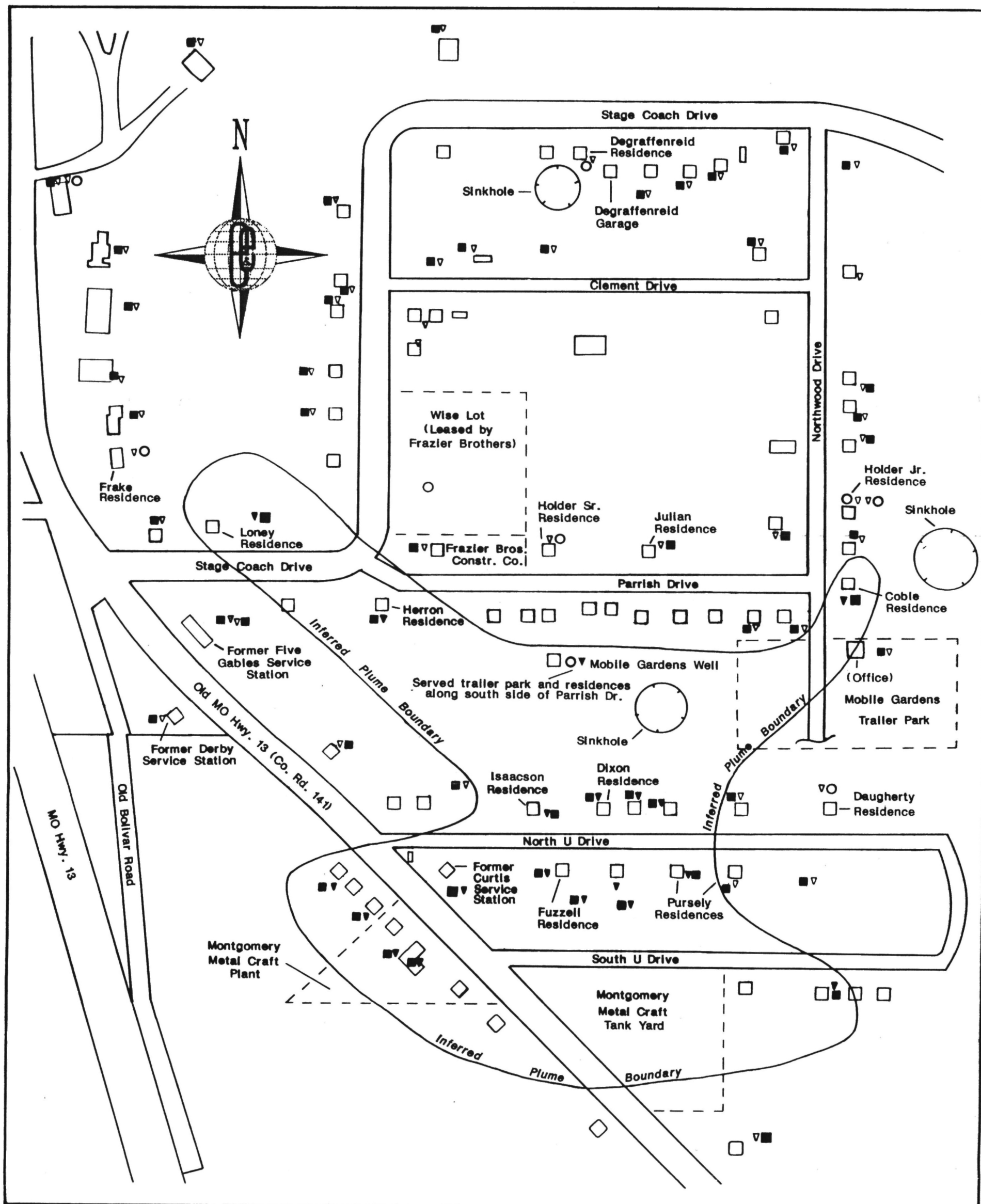
Site Address: 4030 Old Highway 13  
Springfield, Missouri 65803

Property Owner: Mrs. Helen Jones

Address: Rt. 3  
Springfield, Missouri 65803

Phone: (417) 881-5922

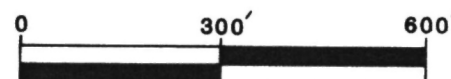
- o **Former Derby Service Station.** This former service station is located directly across the highway (on the west side of Highway 13) from the former Five Gables station. Residents in the neighborhood do not agree on whether underground tanks were ever removed or even used at this station. All structures on the property have been razed, and the lot is vacant. However, one vent pipe remains at the site in what



## NORTH U DRIVE SITE

- ▽ Uncontaminated Well  
 ▼ Contaminated Well  
 ■▽ Plugged Well  
 ○▽ Open Well  
 □ Residence or Other Structure

Scale: 1 inch = 285 feet



**ecology and environment, inc.**

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Date: 9/18/90

Rev. 12/6/90

Figure 1.2-2: Potential Contaminant Sources and Status of Existing Wells

appears to be its original position, indicating that at least one buried tank may still be present.

Site Address: RFD 5, Box 4  
Springfield, Missouri 65803

Property Owner: The Coastal Corporation, Houston, Texas  
Attn.: Hazel R. Hoffman

Address: 9 Greenway Plaza  
Houston, Texas 77046

Phone: (713) 877-1400

- o **Former Curtis Service Station.** This former service station is located at the intersection of Old Highway 13 and North U Drive, on the southeast corner. The site is vacant with no surface structures remaining other than an all-terrain vehicle, resembling an army tank, and a concrete pad which is about 15 by 20 feet in size. The first complaints of "bad water" came from residences along North U Drive adjacent to this property. Accordingly, the former service station was a primary suspect on the list of potential sources.

*Was this  
the North  
U Drive?  
PCB  
leak?*

The EPA Region VII Technical Assistance Team (TAT), was consequently tasked to perform excavation work at the site. Additional information on these studies is included in Section 1.2.3 Previous Investigations.

In addition, at least two long-standing residents of the area (the service station was closed nearly 30 years ago) insist that the station had underground tanks. One of these residents recalled purchasing gasoline at this facility, and even recounted a conversation he had with the station owner in which the latter stated that he knew his tanks to be leaking.

During Phase 1 field activities on this property, a resident living across the highway informed E & E personnel that the former station owner would collect a bucket of water from the station's spigot, and throw a match into the bucket to display the water's ignitability.

This story is unconfirmed, though the well at this property was found to contain as much as one foot of "a petroleum product" on top of the shallow water table (approximately 100 feet below the surface) during previous investigations. This well also contained chlorinated volatile organic compounds.

Site Address: 3932 Old Highway 13  
Springfield, Missouri 65803

Property Owner: Mr. Jack Frazier

Address: 2223 Parish Drive  
Springfield, Missouri 65803

Phone: (427) 833-3123

- o **Montgomery Metal Craft (MMC) Plant.** This facility is located on Old Highway 13, immediately southwest of the former Curtis Service Station. MMC has been in business at least 30 years and has specialized in cleaning, refurbishing and re-coating used storage tanks throughout the last three decades. Until recently, used tanks were cleaned and re-coated outdoors, along the south side of the facility. There is no evidence, from either employee interviews or site files, that any containment apparatus was ever used to collect materials derived from the cleaning process (sludges and cleaning solvents) or the asphalt overspray (containing "cutting" solvents) derived from the re-coating procedures.

Site Address: 3909 Old Highway 13  
Springfield, Missouri 65803

Property Owner: Mr. Lee Montgomery

Address: Same as above

Phone: (417) 833-1515

- o **MMC Tank Yard.** This area, also belonging to Montgomery Metal Craft, is located at the intersection of Old Highway 13 and South U Drive, on the southeast corner. The tank yard, which is partially fenced and entirely unpaved, is used to store new and used storage tanks. Other items on the property include service station fuel dispensers, a drum storage pad (diked), and a tank containment area (also diked) containing three storage tanks, two of which hold diesel fuel.

Site Address: 3909 Old Highway 13  
Springfield, Missouri 65803

Property Owner: Mr. Lee Montgomery

Address: Same as above

Phone: (417) 833-1515

- o **Frazier Brothers Construction Company (FBCC).** This facility is located at the intersection of Stage Coach Drive and Parrish Drive, on the northeast corner. The FBCC is an electrical contractor that has been operating at this location for more than 10 years. According to FBCC personnel, no underground storage tanks have ever been installed at this site. Several trucks and construction vehicles are located on the site and there is also a garage for routine servicing of these vehicles. No spill incidents have ever been reported here, though it is likely that small, isolated releases of diesel fuel or degreasing agents have occurred. It should be noted that the northern 80 percent of this site is actually leased by FBCC and is used as a storage lot for equipment and vehicles. This lot also has an open well, screened in the shallow aquifer, that was sampled during the Phase 1 groundwater investigation. Only the southern portion of the site, containing the garage and offices, is owned by Frazier Brothers. A well located on this portion of the site has been plugged.

*Is the well actually in the aquifer?  
concerning  
plugging  
it.*

Site Address: 2223 Parrish Drive  
Springfield, Missouri 65803

Property Owner: Mr. Jack Frazier  
(FBCC)

Address: Same as above

Phone: (417) 833-3123

Property Owner: Mr. J.H. Wise  
(Storage Lot)

Address: 225 N. Elder  
Springfield, Missouri 65802

Phone: (417) 862-9926

- o **Mobile Gardens Trailer Park (Sinkhole).** Access to the trailer park is from the intersection of Parrish Drive and Northwood Drive. From here, the trailer park extends south, southeast and southwest, encompassing approximately 6 acres. The focus at this property has been on a sinkhole located at the west end of the trailer park. Historically, this sinkhole has been used as a dump for wastes generated by trailer court operations, mostly construction debris. During a reconnaissance of this sinkhole, E & E personnel identified one crushed storage tank (approximate capacity: 500 gallons), and four empty drums amid the construction debris. The sinkhole has been filled with debris, such

that there is no longer a topographic depression. Therefore, it would be reasonable to estimate that as much as 25 to 35 feet of fill has been introduced into this former sinkhole. What lies beneath the surface has not been determined. Neither Richard Thompson, the property owner, nor other local residents were able to provide additional information about the fill content of the sinkhole. However, at least two local residents recalled that one of the former property owners used the sinkhole as a place to burn old cars, which were then removed from the sinkhole and hauled away to be sold as scrap.

Residents also expressed concern that other conditions at the trailer park may pose a threat to the environment. One resident claimed to have witnessed a seep, "smelling like septic waste", flowing from the eastern edge of the property toward the water reservoir. Another citizen indicated that Thompson had filled in an old swimming pool on the property with various refuse. Thompson continues open dumping and burning at an open lot west of the sinkhole, within 100 feet of the open well on that property.

Evidence of a second filled sinkhole northwest of the sink described above has recently been uncovered. This sink may now be covered by trailers.

Site Address: Rt. 20, Box 240-1  
(Office) Springfield, Missouri 65803

Property Owner: Mr. Richard Thompson

Address: Same as above

Phone: (417) 833-1874

**Degraffenreid Sinkhole.** The Degraffenreid residence is located at 2124 N. Stage Coach Drive. Behind this residence is a small sinkhole which is used as a grazing area for a few farm animals. Adjacent to the east edge of this sinkhole is an auto repair garage that Mrs. Degraffenreid leases to a neighbor. This garage has a floor drain which releases into the open environment and directly into the sinkhole. For approximately 23 years, Mrs. Degraffenreid's husband, now deceased, released diesel oil (about 5 gallons every two weeks) into the drain and lesser quantities of anti-freeze, various solvents and possibly other fluids related to auto maintenance. One resident, whose well lies just within the northern boundary of the inferred plume on Figure 1-2, believed his well contamination was directly related to Degraffenreid's disposal practices. His water, he claimed, had an "anti-freeze taste" which disappeared

data to appropriate MONR program

Sinks like a primary source. How far assume it goes into data being to eliminate as a suspected source of contamination.

265 sal / ut  
130 sal / 92  
X2392  
200 gal

after MDNR requested Degraffenreid to halt his disposal activities in 1985. During Phase 1 field activities at this property, E & E personnel noted that this drain was still open and that recent releases to the sinkhole had occurred. Oil pooling was evident beneath the drain outlet. There is currently no visible sign of an "eye" or central drainage opening within this sink.

Site Address: 2124 N. Stage Coach Drive  
Springfield, Missouri 65803

Property Owner: Mrs. Loretta Degraffenreid

Address: Same as above

Phone: (417) 833-1816

- o Coble Sinkhole. The Coble residence is at 4044 Northwood Road, immediately north of the trailer park office. Behind this residence is the center portion of a sinkhole that is much deeper than the Degraffenreid sinkhole, and it covers a larger area than either of the other two sinkholes. No disposal activities were documented to have occurred on this property, nor was there evidence of such activity during the Phase 1 field activities. However, the sinkhole receives drainage from two adjacent properties. Drainage from the south derives from the east end of the trailer park, where several abandoned underground septic tanks (and possibly some butane or propane tanks) may be located. Drainage from the north originates from the neighboring Cook residence, where at least 10 vehicles are stored on an open, unpaved lot. According to Mr. Coble, these vehicles are part of Mr. Cook's automobile collection. This sinkhole contains two discrete low points, or drainage eyes, where run off collects and infiltrates below ground. Both of these eyes are "silted in", such that no underground pathway is visible from the surface, and neither appear to contain stained sediment. No staining is apparent along any of the surface drainage pathways leading to these eyes.

Site Address: 4044 Northwood Road  
Springfield, Missouri 65803

Property Owner: Mr. Harry Coble

Address: Same as above

Phone: (417) 833-9615

The decision to pursue field activities at the listed properties was based upon information collected during file reviews and a visual site reconnaissance performed by E & E personnel. This list is intended to include all discernible possibilities of groundwater contamination sources in the North U Drive neighborhood.

However, during the Phase 1 field activities, two local residents referred to open dumping practices which they believed had taken place east of the Montgomery Metal Craft Tank Yard and south of South U Drive. A walk-over of this area was conducted and noted several locations where solid wastes (mostly hardware scrap) had been deposited. Also noted were two large earthen mounds that appeared to be mixed with or to be covering other debris. Several unmarked drums, each empty, were scattered throughout the area.

Depending upon the conclusions drawn from the Phase 1 investigation, MDNR may wish to assign further investigation into this property.

#### 1.2.3 Previous Investigations

The MDNR initiated its investigation of well contamination in the North U Drive area in November 1983. Subsequent studies have consistently identified several volatile organic compounds in the groundwater. The compounds detected most frequently and in the greatest concentrations are benzene, toluene, ethylbenzene and methyl tertiary butyl ether (MTBE), an anti-knock compound commonly found in gasoline. Table 1.1 is a comprehensive listing of all compounds identified in well samples collected at this site, prior to the RI/FS Phase 1 field investigation. Samples collected before the RI/FS investigation were analyzed for volatile organics only.

Because it was apparent that a groundwater contamination problem existed and further measures were implemented to monitor this problem. Accordingly, the Missouri Department of Health and the Springfield Greene County Health Department issued health advisories, in April and December of 1984, warning against the use of contaminated water for drinking, cooking and bathing.

TABLE 1.1

CONTAMINANTS IDENTIFIED IN GROUNDWATER SAMPLES COLLECTED  
FROM NORTH U DRIVE AREA  
(1983 - 1985)

PRIMARY

Benzene	Toluene
Ethylbenzene	Methyl Tertiary Butyl Ether

SECONDARY

Bromodichloromethane (M624)	Cyclohexane (LS)
Cis-1,3-dichloropropene (M624)	Cyclopentane (LS)
1,1,2,2-Tetrachloroethane (M624)	Methyl-cyclopentane (LS)
Tetrachlorethylene (M624)	Cyclohexene (LS)
3,3-Dimethyl-cyclobutene (LS)	1-Pentene (LS)
2-Methyl-pentane (LS)	2-methyl-butane (LS)
Hexane (LS)	2-Pentane (LS)
Methyl-cyclohexane (LS)	1-Methyl-cyclohexene (LS)
Cyclopentene (LS)	2,3-Dimethyl-2-pentene (LS)
5-Methyl-1,4-hexadiene (LS)	1,2-Dimethyl-benzene (LS)
Methylbenzene (LS)	Butane (LS)
3-Methoxy-3-methyl-2-butanone (LS)	1-Ethyl-3-methylbenzene (LS)
Dichloromethane (LS)	1,2,3-Trimethylbenzene (LS)
1-Ethyl-2-methylbenzene (LS)	4-Methyl-3-heptene (LS)
1-Ethyl-3-methyl benzene (LS)	1,2,3-Trimethylcyclohexane (LS)
2-Ethyl-2-propyl-cyclohexanone (LS)	Diisoamylene (LS)
2,3,4-Trimethylhexane (LS)	
Tris (trimethylsilyl) ester arsenous acid (LS)	
5-(1-Methylpropylidene)-1,3-cyclopentadiene (LS)	

M624 = Identified via EPA Method 624 for volatile organics.

LS = Identified via Mass Spectroscopy library search of peaks. In some cases these identifications are tentative, at best, and all are of a qualitative nature.

On June 7, 1984, a natural gas leakage survey, using flame-ionization equipment, was conducted on all gas mains and service lines owned by the City Utilities of Springfield. The survey detected no leaks.

On August 31, 1984, an extended-term plan to periodically sample wells in the North U Drive area was proposed by MDNR. This plan was to begin on or about October 1, 1984. The following conditions were reported in the MDNR plan:

- likely  
to be a site  
near relative  
to location  
of the  
contaminated  
source*
- 1) Fuzzell well: This well has shown heavy contamination in the past. It appears to have been among the first to become contaminated.
  - 2) Yarrowborough well (now Isaacson residence): Has shown heavy contamination; it may have been the first well to become contaminated.
  - Pursley well: Highly contaminated; has shown greatest concentrations thus far.
  - 3) Dixon well: Appeared to be intermittently contaminated; physically located very near the wells listed above.
  - 4) Mobil Gardens (trailer park) well: A state-approved public drinking water supply well; has shown slight contamination in the past.
  - 5) Montgomery high-yield well: Has not shown contamination in past sampling, but as a high-yield well could be expected to pick up any contaminants migrating to the south-east.
  - 6) Herron well: This well was clean until November of 1984. It is located at the periphery of the contaminated area in the direction groundwater would be expected to move.

Beginning in January, 1985, the EPA Technical Assistance Team (TAT) began studying the design of an alternate water supply for the residents of the North U Drive area. A water main from the City of Springfield was extended to the area and residents were provided with city water in early 1985. After the water lines were installed most of the existing wells were plugged. Six property owners refused to allow the TAT to plug their wells. A total of 68 wells were plugged, while 8 wells were left unplugged. Prior to plugging the existing wells, MDNR's Division

of Geology and Land Survey (DGLS) performed downhole geophysics (gamma logs) in all but 7 wells.

When the DGLS logged the well at the former Curtis Service station (at the intersection of North U Drive and Old Highway 13) about one foot of petroleum product was floating on the surface of the groundwater, at a depth of approximately 105 feet.

Information from neighbors indicated that the gas station had not operated for about 30 years. Since the possibility existed that underground storage tanks might be present, permission was obtained by the EPA from the current owner, Mr. Jack Frazier, on September 11, 1985, to perform exploratory digging in an attempt to trace existing gasoline lines.

During exploratory digging, the backhoe struck the foundation of an old oil-changing pit. This pit was excavated and found to be a poured concrete structure approximately four feet deep, five feet long, and three feet wide. The pit was filled with a variety of debris, and at the bottom, several gallons of what appeared to be used motor oil were mixed in with the soil. Three small PCB contaminated capacitors were found among the debris in the pit, and each were identical in appearance except that two of the capacitors had broken insulators. Later that day the capacitors were removed and the pit was backfilled. Chlor-N-Oil test results indicated that the dielectric fluid in the capacitors contained PCB's, probably in concentrations greater than 50 ppm. During the removal, some PCB's were spilled.

A sampling effort was undertaken by EPA to determine the extent of soil contamination in and around the oil-changing pit. Seven samples were taken. Four of those samples showed PCB concentrations of Aroclor 1248 greater than 50 ppm, and two of those showed concentrations greater than 300 ppm. Aroclor 1254 was also found to be present in lower concentrations. All PCB contaminated soil was subsequently removed by the Region VII TAT. However, it appears that no further excavation ensued following the PCB remediation. *This matter was addressed by EPA as*

Another round of well sampling was conducted by the Laboratory *to remove* Services Program (LSP) on July 16, 1985. Samples were analyzed for *on a separate* *510- NORTH* *Drive PCBs*

volatile organic priority pollutants. A sample from the abandoned gas station well was also analyzed for PCB's.

The water sample from the former Curtis Service Station well contained benzene, toluene and bromodichloromethane. A sample of petroleum product, again found floating on top of the water table in this well, tested positive for those three substances, as well as tetrachloroethylene and chlorobenzene, the latter saturating several laboratory scans with readings as high as 51,000 µg/l.

By November 1985, 12 wells had been determined to be contaminated by a variety of volatile organic compounds and the source of contamination remained unknown.

Water lines were installed in the summer and fall of 1985 to provide Springfield city water to all residences affected, or potentially effected, by the groundwater contamination. Financing for this water-service expansion was provided by a grant from the Community Economic Development agency and the CERCLA removal program.

On January 15, 1986, at the request of the MDNR, samples were collected by the LSP from a septic tank at the Montgomery Metal Craft Plant. A sludge sample from this tank was found to contain ethylbenzene and toluene at concentrations greater than 200 ppb.

Contamination of private water wells near North U Drive is believed, by some residents of the area, to have been caused by compounds leaching from the Fulbright and Sac River landfills. The remedial investigation and feasibility study for these landfills, completed in 1988, did not document groundwater contamination moving in the direction of the North U Drive area.

On October 20, 1988 the TAT was tasked by the EPA to perform sampling along the Sac River immediately north of Springfield. The specific elements were to sample 22 privately-owned wells in conjunction with the Fulbright/Sac River Landfills RI/FS. The TAT sampling effort was conducted from November 28-30, 1988. Sample analysis was performed by EPA Region VII. The case narratives described two deviations from required analytical procedures.

Methylene chloride, commonly used in analytical laboratories and often identified as a "laboratory contaminant" was the only organic compound identified above required quantification limits. Other organics were identified at very low concentrations (1-9 ppb) and qualified with an "M" code (estimated value below the detection limit). Overall, low concentrations of organic compounds were detected in 73% (16 of 22) of the samples. The cumulative total concentrations of organic compounds ranged from 1-54 ppb. The most common organics detected were toluene, tetrachlorethylene, and methylene chloride, all of which appeared in three of the well samples. Methylene chloride was attributed to laboratory contamination.

Detectable levels of metals were found in all the wells sampled. Barium (43-110 ppb), zinc (32-1300 ppb), and magnesium (2.9-25 ppb) were the most common. Lead was detected in 7 (32%) of the wells, at concentrations ranging from 5-10 ppb. Copper (10-1800 ppb) and aluminum (52 ppb) were present in four samples and one sample, respectively. These samples were not filtered and, therefore, the given concentrations represent total levels for each metal. However, the samples were collected directly from household spigots and, having undergone sand-point filtration, the water was essentially free of sediment.

The summary of the report, dated March 6, 1989, noted the very low levels of contamination did not necessitate additional sampling. The groundwater, it was noted, would be continuously monitored by the City of Springfield, utilizing monitoring wells installed on the old landfills. Additional action would be predicated on the detection of significant contamination during well sampling associated with the RI/FS at North U Drive, adjacent to the landfill area.

The MDNR/DGLS, the Springfield City Utilities and Southwest Missouri State University (SMSU) have performed various independent dye-tracing studies to characterize subsurface drainage in the Springfield area. These studies typically utilize sinkholes or wells as injection points for the dye. To date, no sinkholes (or open wells) associated with this site have been included in these studies. Depending upon conclusions drawn from the Phase 1 investigation, the MDNR may wish

to implement a dye-trace study using sinkholes and/or wells in the North U Drive area. Fulbright Spring, a source for the Springfield Municipal Water Supply, is located approximately 2,000 feet east of the nearest contaminated well.

## **2. STUDY AREA INVESTIGATION**

Three periods of field activity associated with physical and chemical site characterization occurred during the Phase 1 investigation. During the first period, July 31, 1990 through August 2, 1990, a topographic survey was performed over the entire study area. Soil-gas and soil sampling were performed in conjunction with geological and contaminant source investigations during the second period of field activities, between October 8, 1990 and October 24, 1990. Finally, the Phase 1 field activities concluded with groundwater sampling of existing wells in the study area between November 11, 1990 and November 17, 1990. This section will discuss the procedures implemented during each of these field events, as well as any deviations from those procedures originally proposed. The results of these field events are discussed in Section 3.

### **2.1 TOPOGRAPHIC SURVEY**

Aerial photographs of Greene County, Missouri, were taken by M.J. Harden on April 2, 1990, for the Greene County Public Works Department, the Greene County Assessor, and the Springfield City Utilities. Elgin Surveying & Engineering of Rolla, Missouri, secured the photographs and provided ground control surveying for the topographic survey. Walker & Associates, of Fenton, Missouri, prepared the topographic base map and enlarged the aerial photograph for use in this investigation.

The study area is set on a ridge overlooking the Little Sac River just north of Springfield, Missouri. The topography is gently sloping to rolling, with steep slopes along the river on the eastern site boundary.

Four sinkholes are located within or very near the study area. Three of these depressions form a linear array; the first is directly west of the Mobile Gardens Trailer Park, the second is directly north of the trailer park (Coble Sinkhole), and the third is northeast of the trailer park. This trend of sinkholes is oriented approximately N. 50° E. across the eastern portion of the study area. The fourth sinkhole is in the north-central part of the study area, on the Degraffenreid property.

The topographic map and aerial photo are provided in envelopes in Appendix A.

## 2.2 SUBSURFACE SOURCE INVESTIGATIONS

The background/source investigation determined that several of the properties under investigation required shallow, subsurface characterization to identify possible buried point sources. The decisions as to which sites should be characterized were based primarily upon the historical information associated with each property. However, some properties were excluded from this physical characterization due to site conditions which precluded the use of surface geophysical techniques. Three of the potential source properties contained too much surface debris to allow such methods to provide substantial data. Five of the six remaining properties lent themselves both historically and physically to some degree of subsurface characterization using the proposed geophysical methods. The Degraffenreid sinkhole, though relatively free of interference sources, was not surveyed. This depression does not exhibit any drainage eyes, nor is there any evidence that open dumping has ever occurred within its boundaries.

### 2.2.1 Methodologies

Terrain conductivity (electromagnetic) and total magnetic field (magnetic) surveys were chosen as the most applicable and complementary geophysical techniques for defining buried point sources, such as buried tanks remaining intact at the former gas stations. At the sinkholes, these techniques would be useful in determining whether debris (not

visible at the surface) has been deposited into any sink exhibiting an eye or throat large enough for subsurface disposal.

The terrain conductivity survey was performed using a Geonics EM-31 terrain conductivity meter. This instrument provides a composite conductivity value for all subsurface materials to a depth of approximately 20 feet. In addition, the EM-31 is sensitive only to those subsurface materials between, and within the approximate vertical plane of, the transmitter and receiver coils.

Terrain conductivity is a function of the type of soil and rock, its porosity and the fluids which fill the pore space. Accordingly, the EM technique is applicable to the assessment of natural hydrogeologic conditions as well as to mapping contaminant plumes, trench boundaries, waste burials, and underground utility lines. At this site, it was expected that any buried tanks, disposal areas, or other buried potential sources could be accurately located using this instrument. It was also expected that any electrolyte (inorganic) plume or dissolved, ionized contaminants, whether derived from a spill or subsurface source, could be delineated using EM techniques. Organic plumes, however, normally are not normally detected by surface geophysical methods.

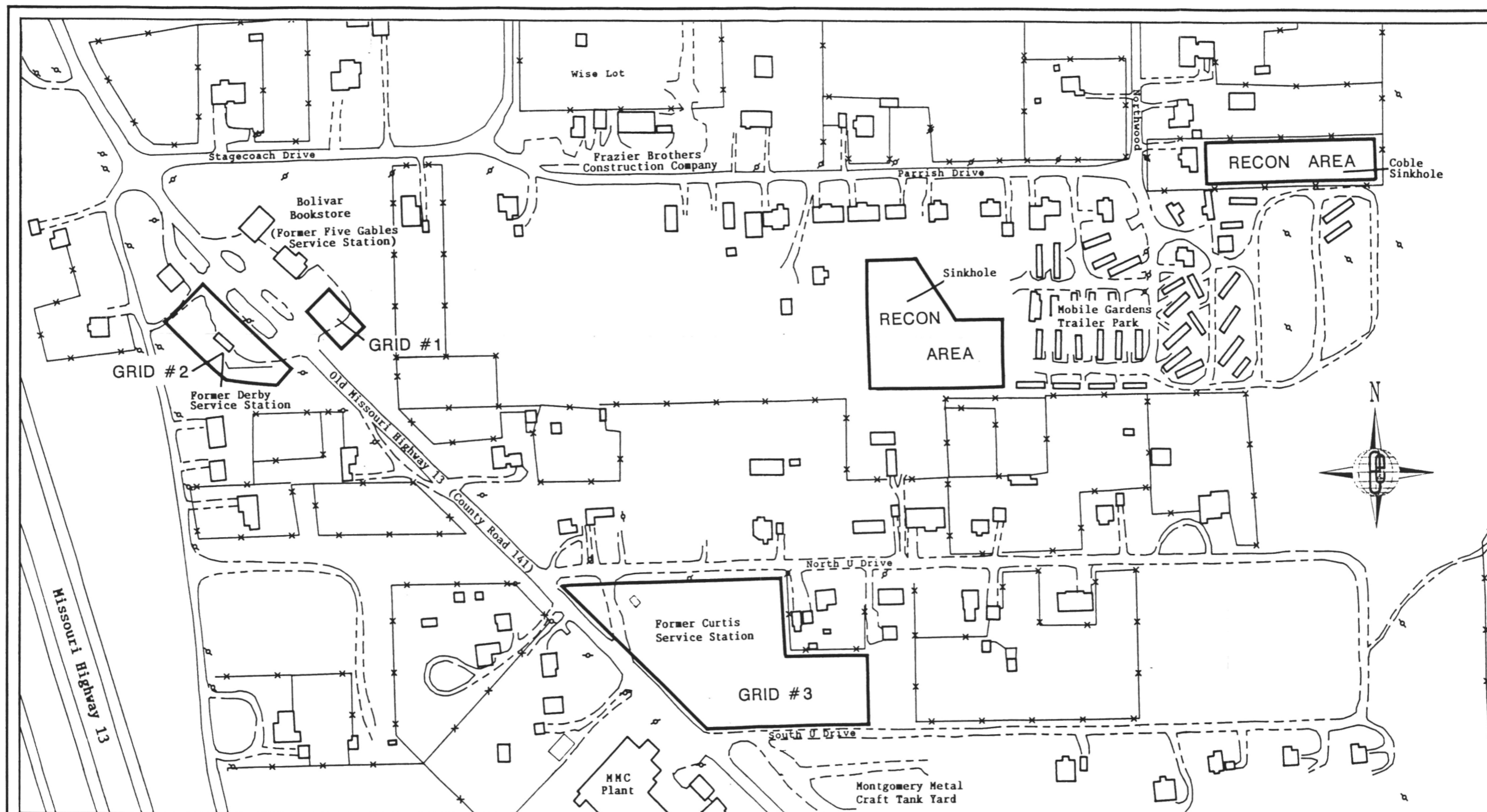
Each terrain conductivity survey was performed in conjunction with a magnetic field survey. The latter was conducted using an EG & G Geometrics G-856 proton magnetometer. This instrument measures the intensity of the earth's magnetic field at a discrete point approximately nine feet above the surface. Subtle variations in this field may be caused by the natural distribution of iron oxides within the soil and rock. More significant changes in the magnetic field intensity are caused by the presence of buried objects composed of steel, iron, or other ferrous alloys. The response of the magnetometer is a function of the object's depth and mass. At this site, the presence of tanks, drums, or other ferrous containers buried within 15 feet of the surface should be detected within the magnetometer data.

### 2.2.2 Survey Procedures

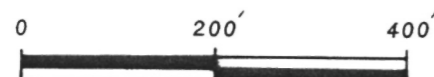
Five properties were subjected to some degree of subsurface characterization via measurements of terrain conductivity and the total magnetic field; the former Derby service station, the former Five Gables service station, the former Curtis service station and the trailer park and Coble sinkholes. At each property, the geophysical investigation commenced with a general reconnaissance using both the EM-31 and the magnetometer. The areas subject to reconnaissance were limited only by surface obstacles which may have prevented the collection of meaningful data. If discrete anomalies were identified during this preliminary stage, a survey grid was constructed around the anomaly to more precisely scrutinize its nature and location. Readings were then recorded at measured intervals along each line of the grid, using both instruments simultaneously. Figure 2.2-1 illustrates the approximate outlines of each area subject to gridding or general reconnaissance. The raw (field) data associated with these geophysical surveys are included as Appendix B-4 with this report.

#### Coble Sinkhole

At the Coble sinkhole, the presence of two accessible openings suggested that at least a walk-over of the area was justified to determine whether any debris had been deposited in the sink. Although these openings have been silted in (possibly a recent development and/or temporary situation) small amounts of scrap metal and wood were noted in and around these drainage points. The property owner claimed the debris (such as pallets and lumber) were intended to keep animals and people from stumbling into the holes. In fact, one of the holes was surrounded by a small wire fence. Prior to the reconnaissance, all non-stationary, metallic debris was temporarily removed to facilitate data interpretation. The amount of metallic debris was very small, with a total mass probably less than that of a single 55-gallon drum. However, it is good practice to clear the survey area of interferences. In general, the amount of effort needed to clear an area should weigh evenly with the likelihood that any significant findings will be made.



Scale: 1 in. = 200 ft.



Surveys Performed October 9 - 18, 1990

Job #: MG2018  
Date: 1/14/91 Prepared by: TMF



ecology and environment, inc.

CLOVERLEAF BUILDING 3, 6405 METCALF  
OVERLAND PARK, KANSAS 66202

Figure 2.2-1 Terrain Conductivity and  
Magnetic Field Survey Areas

No anomalous readings were recorded with either the EM-31 or the magnetometer in or immediately around the sinkhole. Two small burials were identified upon the west flank of the sink, nearer the house. These burials were shallow (less than five feet deep) as determined by negative terrain conductivity readings; however, by virtue of the insignificant magnetic anomalies over these two areas (total fluctuation of 50 to 100 gammas) it was determined that the burials were likely to be no more than pieces of scrap metal. Based upon the locations of these anomalies, the property owner indicated that they were probably related to an old storage shed which had stood in the same general area, but had since been razed. The two locations were flagged for soil-gas sampling, but no gridding or detailed reconnaissance were deemed necessary.

#### Mobile Gardens Trailer Park Sinkhole

Reconnaissance at the trailer park sinkhole was impeded by impassable terrain and dense vegetation. Large pieces of concrete rubble and thick overgrowth consisting of vines and briars made 100% coverage of this area impractical. However, at least 80% coverage was attained and the information gathered was ample for characterizing this area as a potential contaminant source. Based upon the geophysical data, it is safe to consider the entire sinkhole as a landfill. Terrain conductivity and magnetic field measurements varied significantly, and in random fashion, over the sinkhole. Fill material in the sink has been brought up to natural grade (approximately) and there is no evidence that recent dumping has occurred.

Because of the dense vegetation and uneven terrain, gridding this area was not feasible. Aside from this consideration, the amount of useful information gained from gridding this sort of feature is limited. From a geophysical perspective, landfills are composed of "burials-upon-burials", and the overlapping of distorted, or anomalous, electrical and magnetic fields associated with different burials generally makes it impossible to distinguish discrete burials deeper than a few feet. Weighing the excessive amount of time required to grid this area versus the amount of useful information likely to be gained from doing so, it

was decided to limit the geophysical investigation to a reconnaissance.

Using the EM-31 data, several shallow, metallic burials were identified and flagged for soil-gas sampling. The EM-31 is sensitive to shallow metallic objects (less than five feet deep), which are identified by sharp, negative responses on the instrument dial. Any further characterization of such burials is generally not possible through geophysical technology (GPR may provide some additional information) and considering all of the potential metallic items that might be disposed of in an uncontrolled dump, the value of the EM data is obviously very limited.

#### Former Five Gables Service Station (Bolivar Road Newstand)

Reconnaissance at the former Five Gables service station identified a modest anomaly within an area which formerly contained above-ground storage tanks. This anomaly was detected by both instruments and may be a feature related to the operation of those tanks. Considering this feature as a potential source, a survey grid was constructed to better characterize the anomaly. The grid was composed of eight parallel transects oriented approximately N.45°W, parallel to Old Highway 13. The transects were spaced 10 feet apart and varied from 80 to 100 feet in length. Instrument readings from both the EM-31 and the G-856 magnetometer were collected every 10 feet along each survey line. This degree of data density proved to be adequate for defining the physical and spatial magnitude of the anomaly.

#### Former Derby Service Station

At least two significant anomalies were identified during preliminary coverage of the former Derby service station. This facility is believed to have had underground tanks (a vent pipe stills stands on the property), and therefore it was decided to grid the entire premises. The grid consisted of eight parallel transects oriented approximately N.45°W, parallel to Old Highway 13. The first six lines of this grid were spaced 10 feet apart to provide maximum data density between the highway and the former service station building. Lines 7 and 8 were

spaced 15 and 25 feet, respectively, from the next nearest line and were added to the grid primarily to provide sufficient closure west of (behind) the former station building. The transects varied between 130 and 210 feet in length and instrument readings were collected at 10-foot intervals along each line. This spacing will provide more than enough resolution to characterize any tank-size features within the grid.

#### Former Curtis Service Station

Several subsurface anomalies were identified at the former Curtis service station during the reconnaissance phase at this property. Burials were more numerous within the northwest corner of the site, where the service station building once stood. However, additional disturbances were also identified as far west as the Fuzzell residence, within the southeastern arm of the property. Consequently, the entire lot was gridded to ensure that no disturbance would be overlooked. The base grid consisted of 23 parallel transects, which were oriented approximately N.0°E. These transects were 25 feet apart and varied between 37.5 feet (in the northwest corner) and 250 feet (in the center of the lot) in length. In areas which required better resolution, intermediate lines were added to provide 12.5 spacings between transects. Readings from both instruments were recorded at least every 25 feet along each line. Again, where better resolution was required to define an anomaly, instrument readings were recorded as frequently as every 12.5 feet.

Before commencing the reconnaissance at each of the properties, the EM-31 was subject to several functional checks. After a battery check, the instrument was subject to phasing and sensitivity checks to ensure that it was functioning properly, and in a consistent manner.

As a QA measure for the magnetometer surveys, an operator "quick-check" was performed prior to collecting the field data each day. To perform this check, the operator observes magnetic field measurements while standing at various orientations about the instrument. If these readings do not vary more than 1 or 2 gammas, the operator is assured that he or she is not influencing the magnetic field by means of magnetically susceptible personal gear. Although this degree of noise resolu-

tion may not be necessary to assure proper identification of buried tanks or drums (which themselves may create anomalies on the order of hundreds or thousands of gammas), it must be considered to help keep the overall survey interferences, some of which are not correctable, to a minimum.

The EM-31 and magnetometer data was generally unaffected by cultural (or non-correctable) interferences, such as fences, powerlines and utilities, nor were the diurnal variations of significant magnitude to warrant data reduction. However, in some areas the presence of interference sources precluded the use of one or both of the instruments. These obstacles are noted on the field sheets included in Appendix B-4 with the report. In instances where the data was severely affected, the appropriate data points were excluded from interpretive analysis. Data presentations for all terrain conductivity and magnetic field investigations are included in Section 3.6.

### 2.3 SOIL AND SOIL-GAS INVESTIGATIONS

The Soil and Vadose Zone field investigations tasks conducted in this phase included a soil-gas survey and shallow subsurface soil sampling. Access consents to all properties were obtained prior to field activities. Although representatives of the majority of the properties under study were present, representatives for the former Five Gables service station and the former Derby service station were not present during field work.

#### 2.3.1 Soil Sampling

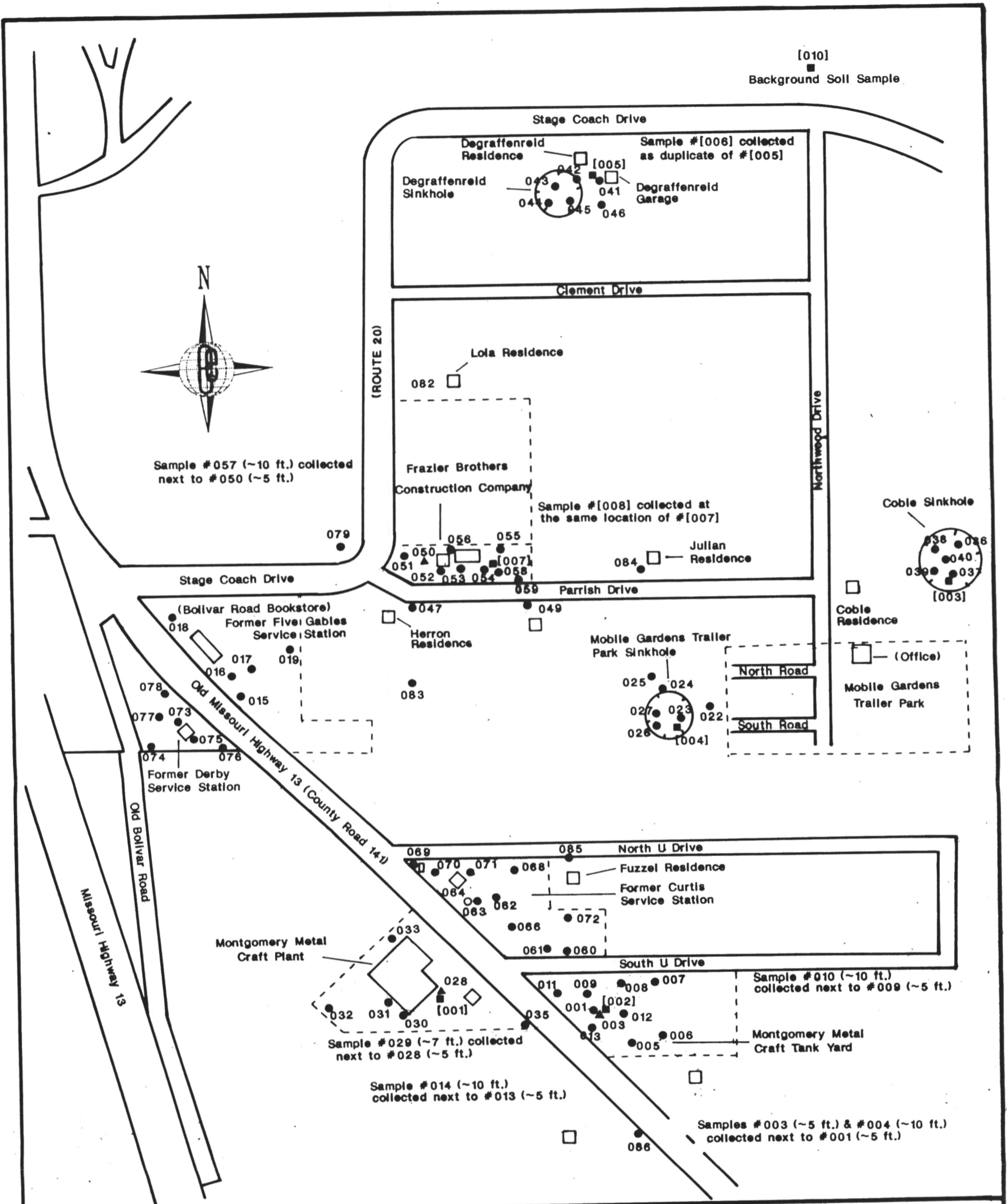
Soil samples were collected at seven locations representing potential surface contaminant pathways. Samples locations are shown on Figure 2.3-1. These locations were within the following areas:

- 1) Montgomery Metal Craft plant area (west of Old Highway 13);
- 2) Montgomery Metal Craft tank yard (east of Old highway 13);

- 3) The sinkhole near the northeastern portion of the Mobile Gardens Trailer Park (Coble sinkhole);
- 4) The sinkhole west of the Mobile Gardens Trailer Park (Mobile Gardens Trailer Park sinkhole);
- 5) The sinkhole on the Degraffenreid property (Degraffenreid sinkhole);
- 6) Frazier Brothers Construction Company (West Stage Coach and Parish); and
- 7) Background location collected at the north end of the Northwood Drive.

Samples for volatile organics analysis were collected using a Geoprobe Model 8-A hydraulically-powered soil probe unit. A steel sampling tube attached to the probe rod was pushed through the soil to an initial depth by the hydraulic unit. A piston, which prevented soil from entering the sample tube, was then withdrawn allowing soil to move freely. The sample tube was then pushed deeper and a soil sample, approximately 8-inches long and 1/2 inch in diameter, was collected in the tube. The probe was removed from the ground and the soil sample extruded from the sample tube. Aliquots were collected for non-volatile samples with the Geoprobe Unit in two locations (Montgomery Metal Craft plant and tank yard). These aliquots were collected about five feet from each other and homogenized in disposable aluminum pie pans using stainless steel spoons. To avoid air stripping of volatile compounds, soil samples for the volatile fraction were not composited or homogenized.

Site conditions prevented Geoprobe van access to two sampling locations. Also because soil lithology sometimes prevented suitable recovery in the sampling tube, samples were collected using a "slam-bar" and shelby tube or a portable power auger. The slam-bar with the Geoprobe's 1/2" pipe rod was used at the Coble sinkhole and the Mobile Gardens Trailer Park sinkhole for all parameters. The portable power auger was used to collect of the non-volatile parameters at the Degraffenreid and Frazier Brothers properties; the Geoprobe unit retrieved the soil samples for volatile analysis at these two locations. Sample depths ranged from 1 to 3.5 feet below the surface and samples



# NORTH U DRIVE SITE

<b>SOIL-GAS SAMPLE SERIES MG2016-SG-</b>		<b>SOIL SAMPLE SERIES MG2014-S-</b>	<b>Scale 1 inch = 285 feet</b>
001: Soil-Gas Sample Number		[001]: Soil Sample Number	
● : Shallow Soil-Gas Sample (~5 feet)		□ : Residence or Other Structure	
○ : Deep Soil-Gas Sample (~10 feet)		■ : Soil Sample (~5 feet)	
▲ : Shallow and Deep Soil-Gas Samples			
		<b>MG2018</b>	<b>PREPARED BY: OS</b>
			<b>Date: 1/04/91</b>
			<b>Rev.: 1/21/91</b>

Figure 2.3-1: Locations for the Soil and Soil-Gas Samples

were homogenized in the same manner as with the Geoprobe, except for the volatile fraction.

Decontamination of the sampling equipment was in the same manner as the soil gas surveys described below. A water rinsate sample of the sampling equipment was collected and analyzed for QA/QC purposes.

One duplicate sample was collected at the Degraffenreid property for QA/QC purposes (Figure 2.3-1). Split samples from sampling activities at the Frazier Brothers Construction Company were provided to Mr. Ted Salveter, the on-site engineer for McLaren Hart Consultants, representing Frazier Brothers.

Samples were placed into 40 ml glass vials with a teflon septa for volatile organic compound analysis and into 8 oz. glass jars for all other analyses. Sample containers, preservatives, handling and labeling followed the Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP). These procedures, provided in the FSP and QAPP, are not detailed in this report.

Field activities produced a total of nine soil samples, and one water rinsate sample. Table 2.3-1 summarizes soil sampling, and Figure 2.3-1 shows the locations. The sample series assigned for this activity is MG2014-S. Soil samples were collected in Level D personal protection, and shipped to the E & E Laboratory in Buffalo, New York, via Federal Express for the following analyses: volatile organics (VOAs), methyl tert-butyl ether (MTBE)(volatile-fractions); total metals, cyanide and base, neutral and acids extractable analysis (non-volatile fractions). All analytical procedures follow the EPA Contract Laboratory Program (CLP) protocols. Analytical results for soil sampling are presented in Section 4 of this report. An MSA 260 Oxygen/Explosimeter ( $O_2$ /Explosimeter), HNu and/or OVA provided continuous air monitoring in the breathing zone and inside of the boreholes.

#### Montgomery Metal Craft Plant

One soil sample [001], approximately 3.5 feet below surface, was collected at the Montgomery Metal Craft plant on October 11, 1990. The

TABLE 2.3.1

SOIL SAMPLE SUMMARY FOR NORTH U DRIVE  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SAMPLE SERIES M32014-S

	SAMPLE NUMBER									
	001	002	003	004	005	006 (3)	007	008	009 (4)	010 (5)
	SAMPLE LOCATIONS									
	MONTGOMERY'S PLANT	MONTGOMERY'S TANK YARD	COBLE'S SINKHOLE	MOBILE GARDEN'S SINKHOLE	DEGRAFFENREID SINKHOLE	DEGRAFFENREID SINKHOLE	FRAZIER BROTHERS	N/A	(RIMSATE)	STAGECOACH AND NORTHWOOD DRIVE
Date	10/11/90	10/11/90	10/12/90	10/12/90	10/16/90	10/16/90	10/17/90	10/18/90	10/19/90	10/19/90
Time	12:30 (1)	18:10	16:00	17:45	15:00	15:00	18:00	9:00	17:40	16:30
Depth	3.5 feet	3.5 feet	0-1 feet	0-2 feet	3-4 feet	3-4 feet	4-5 feet	4-5 feet	N/A	0-1 feet
Aliquots (2)	3	5	5	5	5	5	1 (6)	5 (7)	N/A	1
Split	No	No	No	No	No	No	Yes	Yes	No	No

Notes: The samples were submitted for low detection limit volatile organics (VOAs) and MTBE, total metals, cyanide, base/neutral and acid, and pesticides analysis. See Figure 2.3.1 for sample locations.

(1) : Sample collected for VOA and MTBE at 12:30 hours; other non-volatile parameters were collected at 16:00 hours.

(2) : All samples for VOA and MTBE were collected from single boreholes, and were not homogenized.

(3) : Sample #006 is a duplicate sample of #005.

(4) : Sample #009 is an equipment rinsate (water sample) for QA/QC purposes.

(5) : Background soil sample collected at 100 feet north of the intersection of Stagecoach Drive and Northwood Drive.

(6) : Only sample for VOA and MTBE was collected at this date; sample for other non-volatile parameters were collected on October 18, 1990.

(7) : Only sample for sample for non-volatile parameters were collected at this date; sample for VOA and MTBE was collected on October 17, 1990.

Geoprobe unit retrieved the sample for volatile organics fraction, while samples for the other parameters were collected with the powered auger. The pattern of sample aliquots for the non-volatile samples were linear due to the utilities restrictions. Figure 2.3-1 depicts the sample location.

The Montgomery Metal Craft personnel called the City of Springfield Utilities (Gas Leak Survey Division) when informed by the E & E site safety officer of a possible gas leak detected by the field monitoring instruments ( $O_2$ /Explosimeter and OVA), near the southeast corner of the manufacturing building (Sample [001], Figure 2.3-1). Garry Corson, a gas-leak surveyor (City Utilities) collected two soil-gas samples, which were unofficially reported as containing propane among other unidentified compounds. At this time, the official results for these two soil-gas samples are not available. At no time were readings above background detected in the breathing zone. Inside the boreholes, HNu readings ranged from 5 to 30 parts per million (ppm) above background (0.2 ppm); OVA readings were above 1000 ppm (background was 0 ppm); and  $O_2$ /Explosimeter readings were 60% of the lower explosive limit (LEL). The low concentrations found with the HNu is indicative of methane or propane, both of which have low relative response on this instrument when using the 10.2eV bulb.

#### Montgomery Metal Craft Tank Yard

One soil sample [002], approximately 3.5 feet below ground surface, was collected at the Montgomery Metal Craft tank yard on October 11, 1990. The Geoprobe unit was used to retrieve the sample for volatile organics analysis while samples for the other parameters were collected using a powered auger. Sample aliquots for the non-volatile samples were evenly spaced from a central node. Figure 2.3-1 shows the sample location. No readings above background were detected in the breathing zone at anytime. Inside the boreholes, HNu readings ranged from 4 to 5 ppm above background (0.2 ppm); OVA readings were 200 ppm above background; and  $O_2$ /Explosimeter readings were non-detects.

### Coble Sinkhole

One soil sample [003], approximately 1 foot below surface, was collected at the Coble sinkhole, north of the Mobile Gardens Trailer Park area on October 12, 1990. A slam-bar and the Geoprobe's 1/2" pipe rod was used to retrieve the sample for volatile organics fraction, while samples for the other parameters were collected with a shelby tube driven by the slam bar. Sample aliquots for the non-volatile samples were evenly spaced from a central node. Figure 2.3-1 depicts the sample location. No readings above background were detected in the breathing zone at anytime. Inside the boreholes, HNu readings ranged from 0 to 5 ppm above background (0.2 ppm); OVA and O<sub>2</sub>/Explosimeter units were not used at the Cobel sinkhole.

### Mobile Gardens Trailer Park Sinkhole

One soil sample [004], approximately 2 feet below surface, was collected at the Mobile Gardens Trailer Park sinkhole on October 12, 1990. The slam bar and the Geoprobe's 1/2" pipe rod was used to retrieve the sample for volatile organics fraction; other parameters were collected with a shelby tube driven by the slam-bar. Sample aliquots for the non-volatile samples were evenly spaced from a central node. Figure 2.3-1 depicts the exact sample location. No readings above background were detected in the breathing zone at anytime. Inside the boreholes, HNu readings ranged from 4 to 5 ppm above background (0.2 ppm); OVA and O<sub>2</sub>/Explosimeter units were not used at this site.

### Degraffenreid Sinkhole

Two soil samples [005 and 006], approximately 3.5 feet below surface, were collected at the Degraffenreid sinkhole on October 16, 1990. Sample [006] was collected as a duplicate of sample [005] for QA/QC purposes, and was designed to assess the consistency of the overall sampling and analytical system. The Geoprobe unit was used to retrieve the sample for volatile organics analysis, while samples for the other parameters were collected with the powered auger. Sample aliquots for the non-volatile samples were evenly spaced from a central node. Figure

2.3-1 depicts the sample location. No readings above background were detected in the breathing zone. Inside the boreholes, HNu readings were background, (0.2 ppm); and the OVA reading was 1 ppm above background. The O<sub>2</sub>/Explosimeter unit was not utilized at this location.

#### Frazier Brothers Construction Company

One soil sample [007], approximately 4.5 feet below surface, was collected at the Frazier Brothers Construction Company on October 17, 1990. Sample [007] was collected only for the volatile organics fraction in order to provide a split sample to McLaren Hart (representing Frazier Brothers). This sample was collected with the Geoprobe Unit. At no time were readings above background detected in the breathing zone. Inside the boreholes, the OVA reading was more than 1000 ppm. The HNu and O<sub>2</sub>/Explosimeter units were not utilized at this location.

Sample [008] was collected approximately 4.5 feet below surface for non-volatile parameters on October 18, 1990. The sample was retrieved with a powered auger. Sample aliquots for the non-volatile parameters were evenly spaced from a central node. A split of this sample [008] was provided to McLaren Hart. At no time were readings above background detected in the breathing zone. Inside the boreholes, OVA readings were 30 ppm above background. The HNu and O<sub>2</sub>/Explosimeter units were not used here. Figure 2.3-1 depicts the samples locations.

#### Background Soil Sample

One background soil sample [010], approximately 18 inches below ground surface, was collected 100 feet north of the intersection of Northwood Drive and Stage Coach Drive on October 19, 1990. The sample, collected in an area of woods, was taken using a shovel and shelby tube. First, a shovel was used to dig into the firm soil approximately 8 inches. The shelby tube was then driven into the ground to a depth of 18 inches. This background soil sample was a grab sample (i.e., one aliquot). It was to be analyzed for both volatile and non-volatile parameters. The OVA reading at this sample location was 0 ppm (same as background).

### Field Equipment Rinsate

One water sample [009], as rinsate of the field equipment, was collected on October 19, 1990. This rinsate sample was collected to demonstrate that sampling equipment was properly prepared and cleaned before field use and that cleaning procedures between samples were sufficient to minimize cross-contamination. The rinsate blank was prepared by passing analyte-free water over the sampling equipment after decontamination. The sample was submitted for analysis for all applicable parameters.

### Equipment Decontamination Procedures

Sampling equipment used more than once was decontaminated between locations according to the work plan and QAPP in compliance with established E & E and EPA procedures. Non-disposable field equipment was decontaminated by scrubbing the equipment with brushes to remove all foreign material, then washing with an Alconox/deionized water solution until visibly free of foreign material, then triple-rinsing with deionized water.

### Sample Containers

The volumes and containers required for the sampling activities strictly followed the QAPP. These pre-washed sample containers were obtained from a reliable supplier and were provided by E & E's Analytical Services Center (ASC). All containers were prepared according to the current EPA bottle-washing procedures required for CERCLA investigations.

### Sample Custody

Sample chain of custody was maintained by E & E sampling personnel and E & E's ASC. Field custody and sample documentation procedures followed established E & E and EPA protocols and is described in the QAPP.

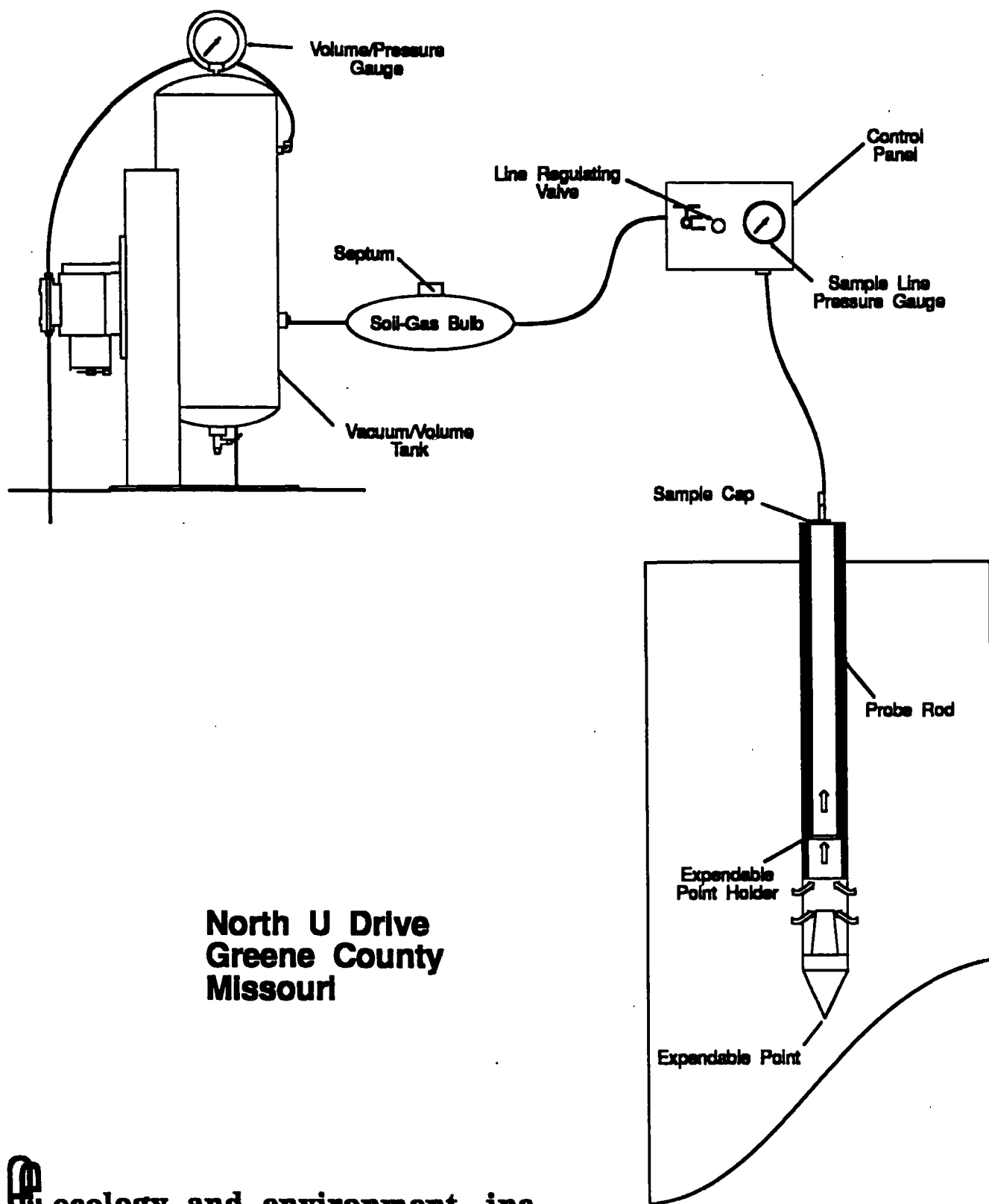
### 2.3.2 Soil-Gas Survey

The soil-gas survey was primarily designed to identify and isolate potential sources of groundwater contamination near the site. A secondary objective was to determine potential contaminant plumes.

Nine potential sources have been identified for the contamination associated with the North U Drive site. Figure 2.3-1 shows the location of the surveys. These sources are described in the order they were investigated:

- Montgomery Metal Craft tank yard;
- former Five Gables service station); (presently Bolivar Road Newstand)
- Mobile Gardens Trailer Park sinkhole;
- Montgomery Metal Craft plant;
- Coble sinkhole (north of the Mobile Gardens Trailer Park);
- Degraffenreid property sinkhole;
- Frazier Brothers Construction Company;
- former Curtis service station (at the intersection of North U Drive and Old Highway 13); and
- former Derby service station.

Soil-gas samples were collected using established E & E protocols. A 1-inch O.D. hollow steel pipe was inserted to a predetermined sampling depth through the use of a truck-mounted hydraulic ram fitted with a hydraulic hammer, the Geoprobe. If this insertion tool could not access a sampling point, a "slam-bar" was used to insert the soil gas probes. Figure 2.3-2 shows the soil-gas apparatus. The steel pipe or soil-gas rod has an I.D. of 0.5 inch. Each rod is three feet long and fitted with Acme-style flush threads. Teflon tape was applied to the male threads prior to rod assembly to assure an airtight seal at joints. The first rod was fitted with an expendable drive point made of carbon steel. Once the soil-gas rod was advanced to the predetermined sampling depth it was retracted approximately six inches. The expendable drive



**Figure 2.3-2: Soil-Gas Apparatus**

point remained at the bottom of the hole leaving a 6-inch long by 1-inch diameter chamber or void. This void in the soil allowed soil gas to be drawn into the soil-gas rod when a vacuum was applied to the top of the rod. The top of the rod was fitted with a sampling head which allowed the attachment of a vacuum line to the soil-gas rod. A vacuum gauge and sampling bulb were placed in-line between the sampling head and the vacuum pump. The vacuum gauge was attached between the sampling head and the sampling bulb, allowing constant monitoring of the sampling conditions. Prior to collecting a sample, three volumes of air were purged from the sampling system. Each soil-gas rod has an annular volume of approximately  $100 \text{ cm}^3$ . Once the appropriate presampling volume was purged from the system, the sampling bulb stopcock on the vacuum pump side was closed. This initiated the sample-collection phase of the task. Sample collection continued until the volume of soil-gas drawn through the bulb totally displaced the volume of air previously contained in the system. A vacuum flow-rate of 100 ml/min. was calibrated at each location with an in-line rotometer. As each Geoprobe rod's annular volume was  $100 \text{ cm}^3$ , two rods put end-to-end to provide a sampling depth of five feet held  $200 \text{ cm}^3$ , or ml. On the average, six minutes of purging displaced three volumes of the soil-gas apparatus. Another three minutes at the same 100 ml/min. flow-rate assured representative soil-gas within the sample bulb. At this point the sampling bulb stopcock on the soil-gas rod side was closed. The vacuum pump was then stopped and the sampling bulb was delivered to FASP personnel for analysis. For any duplicate sample, a second sampling bulb was installed in the system and the sampling procedure was repeated, minus the initial purging phase.

Samples were analyzed within one hour, with some exceptions due to delivery and/or analysis problems. When the soil-gas holding time was exceeded the analytical results were not invalidated, rather they were flagged as an estimated value.

The final number of sampling points around a particular potential source depended on the size of the potential source and the degree of detected contamination. Initially all sources except the Montgomery Metal Craft tank yard were considered the same size, with the tank yard

considered twice the size of the other eight potential sources. However, field analysis of the soil-gas warranted collection of more than the initial five samples taken around the eight smaller locations, as described below. The centroid of each potential source was identified and sampled. An attempt to establish additional sampling nodes approximately 100 feet north, south, east, and west was made, however the actual spacing had to accommodate soil lithology and topography as shown on Figure 2.3-1.

The soil-gas survey produced a total of 87 samples, including duplicate samples, equipment blanks and ambient air blanks. If no volatile organics were detected in the soil gas around a sample point it was discounted as a potential source. After the initial sampling effort, detections were plotted on a site map and an expanded sampling grid was established to aid in the delineation of the areal extent of the soil-gas plume for each individual source. Quality Assurance and Quality Control (QA/QC) were provided by the collection of one sample duplicate, laboratory sample duplicates, field sampling equipment blanks, and ambient air blanks. The ratio of samples to duplicates was approximately 10:1 for this site. Equipment blanks were run on all decontaminated sample bulbs and on decontaminated soil-gas rods used on sampling locations that showed contamination.

The duration of this sampling effort was contingent on the relative ease of installing soil-gas rods, sample extraction, and the presence or absence of detectable contaminants in the soil gas. Although E & E estimated one sampling team would be able to sample 20 locations per day, only an average of 12 samples per day were collected due to soil lithology and topography. Additionally, a replacement for the initial GC instrument was necessary, delaying the soil-gas survey start-up date three days.

#### Soil-Gas Sampling Collection Method

Soil-gas sampling attempted to identify the existence of a soil-gas plume within the vadose zone around each potential source and quantify its relative intensity. Due to the number of potential sources, and the

similarity of the proposed soil-gas sampling techniques at each location, a single methodology was detailed in the work plan for this RI/FS. Slight variations of this methodology were implemented during field activities to accommodate field conditions. These variations involving a number of sampling points are described in the specific field activities for each potential source.

#### Soil-Gas Sampling Analysis Method

An SRI 8610 Gas Chromatograph (GC) equipped with a capillary column and an HNu Photoionization Detector (PID) was used to quickly identify compounds in the soil-gas samples. A Spectraphysics SP4200 Integrator was used for data acquisition. Established E & E Field Analytical Screening Program (FASP) protocols were used for the analytical portion of this survey. Calibration standards were prepared in solvent (methanol) to a known concentration, allowing the total weight injected, in nanograms, to be calculated. Samples were collected in 250 mL glass bulbs with polymer stopcocks and standard septa. Aliquots of 1 mL were withdrawn from the bulb using a gas-tight syringe and injected into the instrument for analysis. Blanks and duplicates (laboratory and field) were analyzed to check for contamination and for precision of the field and laboratory efforts providing good QA/QC.

The analytes of interest were benzene, toluene, ethylbenzene, o-xylene, trichloroethylene (TCE), and tetrachloroethylene (PCE). Also available for conclusive identification were methyl tert-butyl ether (MTBE) and several halogenated compounds (dichloroethene (DCE), trichloroethane (TCA), and others).

A three-point calibration was performed using the analytes in methanol. The relative standard deviation calculated showed that TCE and PCE did not yield a linear response due to solvent contamination and/or detector characteristics. Therefore, results for TCE and PCE were flagged ("J") as estimated. The benzene/toluene/ethylbenzene/xylene (BTEX) compounds gave a linear response during calibration. Methyl tert-butyl ether (MTBE) co-eluted with the solvents used for calibration and so a quantitative assessment could not be made. Headspace standards were

injected in order to provide a qualitative (tentative) identification of peaks in some samples. This identification is obviously subject to interference.

Quantitation limits for all analytes were determined to be 1 ng/mL. Unidentified compounds were quantitated using the integrator response (area) obtained and the response factor calculated for benzene to give an estimated quantity for non-target compounds.

A stock standard aliquot was spiked into a sample bulb and analyzed after evaporation of the spike. This allowed the expected retention time shift for gaseous-versus-liquid compounds to be accounted for during sample assessment. In relative terms, a decreased response for the heavier analytes (ethylbenzene and o-xylene) was noted. This would be expected due to their lower vapor pressure.

On three occasions during the field effort, an external radio source introduced noise interference to the chromatograms obtained during analysis. This noise was unpredictable and unavoidable, and the source could not be identified. A similar effect was observed on other site investigations (which utilized GCs) when a walkie-talkie radio was used to transmit while in close proximity to the instrument/integrator. The effect of this noise was to preclude identification of trace level contaminants in samples, if present. However, significant contamination was detectable above the noise, as when standards were analyzed. Useful information was still obtained from the analysis.

The work plan stated that samples not analyzed within one hour would have invalidated results. However, it should be noted that the soil-gas survey is a screening technique used to present relative indications of contamination and tentative identifications, where possible. In addition, a sample showing moderate contamination was held overnight at room temperature, not exposed to sunlight, and reanalyzed the following day as a test. It yielded comparable results to those obtained from the original analysis. In a few instances, samples were not analyzed within one hour due to delivery and/or analysis problems. These results were flagged ("J") as estimated and should be considered useful for the purposes of the study.

### Soil-Gas Sampling

The sample series for this soil-gas activity was MG2016-SGS. Figure 2.3-1 depicts sampling locations. The soil-gas field analytical results are discussed in Section 4.

### Montgomery Metal Craft Tank Yard

The soil-gas sampling at the Montgomery Metal Craft tank yard was conducted on October 13, 14, and 19, 1990. Sixteen soil-gas samples were taken within the tank yard area. Sample numbers were 001 through 014, and 086 and 087. One duplicate sample (004) and two ambient air blank samples (002 and 087) were collected for QA/QC.

### Former Five Gables Service Station

The soil-gas sampling at the former Five Gables service station (Bolivar Road Bookstore) was conducted on October 14, 1990. Seven soil-gas samples were taken within the bookstore property. Sample numbers were 015 through 021. One field equipment (020) and one ambient air (021) blank sample were collected for QA/QC purposes.

### Mobile Gardens Trailer Park Sinkhole

The soil-gas sampling at the Mobile Gardens Trailer Park sinkhole was conducted on October 14 and 15, 1990. Six soil-gas samples were taken within the sinkhole area. Sample numbers were 022 through 027. No field equipment or ambient air blank samples were collected at this location.

### Montgomery Metal Craft Plant

The soil-gas sampling at the Montgomery Metal Craft plant was conducted on October 15, 1990. Eight soil-gas samples were taken around the manufacturing plant. Sample numbers were 028 through 035. One field equipment blank sample (034) was collected for QA/QC purposes.

#### Coble Sinkhole

The soil-gas sampling at the Coble sinkhole was conducted on October 15, 1990. Five soil-gas samples were taken within the sinkhole. Sample numbers were 036 through 040. No field equipment blank sample was collected at this location.

#### Degraffenreid Sinkhole

The soil-gas sampling at the Degraffenreid sinkhole was conducted on October 16, 1990. Six soil-gas samples were taken within the sinkhole area. Sample numbers were 041 through 046. No field equipment or ambient air blank samples were collected here.

#### Parrish Drive and Stage Coach Drive

The soil-gas sampling along Parrish Drive and Stage Coach Drive was conducted on October 16 and 19, 1990. Nine soil-gas samples were taken along these two roads. Sample numbers were 047 through 049, and 079 through 084. One field equipment (080) and two ambient air (048 and 081) blank samples (048 and 081) were collected for QA/QC.

#### Frazier Brothers Construction Company

The soil-gas sampling at the Frazier Brothers Construction Company was conducted on October 17 and 18, 1990. Ten soil-gas samples were collected on the company's property. Sample numbers were 050 through 059. No field equipment or ambient air blank samples were collected at this location.

#### Former Curtis Service Station

The soil-gas sampling at the former Curtis service station was conducted on October 18 and 19, 1990. Fourteen soil-gas samples were obtained at the location, owned by Frazier Brothers Construction Company. Sample numbers were 060 through 072, and 085. No field equipment or ambient air blank samples were collected at this location.

#### Former Derby Service Station

The soil-gas sampling at the former Derby service station was conducted on October 19, 1990. Six soil-gas samples were collected at this former gasoline service station. Sample numbers were 073 through 078. No field equipment or ambient air blank samples were collected at this location.

#### Decontamination of Soil-Gas Equipment

After each sample collection the soil gas rods were withdrawn from the soil and decontaminated. This procedure consisted of external cleaning of the rods and subsequent heating to drive off possible contamination by volatile organic compounds. A portable heater with 150,000 BTU capacity was used to heat the rods for more than 20 minutes during each decontamination procedures. The external cleaning was accomplished by a solution of Alconox and deionized water wash. Equipment blanks were collected to validate the decontamination procedures. Sampling bulbs were also decontaminated with heat and checked in a similar manner. A portable vacuum pump and a hair dryer were used for air and volatile contaminants extraction. Sampling bulbs were analyzed after decontamination to assure the absence of contaminants in the bulbs.

#### Investigation-Derived Waste

The work associated with Phase 1 was performed in level D protection. However, small quantities of disposed Personnel Protective Clothing (PPC) were generated. Any PPC determined not to be contaminated was disposed of in a double-lined plastic bag and taken to the local municipal landfill. Any PPC determined to be potentially contaminated was placed into a 55-gallon DOT-approved drum with a double-plastic liner. The drums were labeled and placed in an on-site secure area until disposition can be determined by MDNR.

### Deviation from the Work Plan

Regarding the soil-gas activities, all three guidance documents state that duplicate soil-gas samples were to be collected as part of the QA procedures. However, because an air sample cannot feasibly be homogenized and separated into different containers under field conditions, soil-gas "duplicates" were developed as an alternate in the laboratory; that is, laboratory splits were prepared from a single field sample. This type of QA protocol is useful in estimating the analytical precision of any given laboratory procedure.

## 2.4 GEOLOGICAL INVESTIGATIONS

Three geophysical methods, seismic refraction, resistivity, and very low frequency (VLF) electromagnetics were used to characterize shallow geology at the North U Drive study area. Specifically, these techniques were employed to help create a map of the competent bedrock surface beneath the study area, and also identify potential subsurface conduits (faults, fractures, etc.) for contaminant migration. In this section, each of these geophysical methods will be introduced with a brief explanation of the principals involved, followed by the methods and procedures used at this site. The survey results are addressed and interpreted in Section 3.3.

### 2.4.1 Seismic Refraction Survey

The seismic method of subsurface exploration utilizes the basic physics of wave propagation, reflection and refraction in media exhibiting different physical properties. There are three major system components needed for the acquisition of seismic data:

- o SHOT. This is the energy source that generates seismic (or acoustic) waves through the subsurface;
- o RECEIVER. This instrument, usually called a geophone, converts the ground motion, caused by seismic waves, into a proportional electrical signal; and
- o RECORDER. This electrical instrument converts and stores the signals from the receiver into positive or negative integers of

varying amplitudes that correlate with the ground motion intensity and direction (up or down) at the receiver. The recorder continuously samples each receiver at a discrete time interval until a user-specified total time initiated at the shot is reached. The completed result is a seismic record.

An idealized layout for a seismic survey is shown in Figure 2.4-1. This figure also illustrates selected travel paths (raypaths) from a shot to a geophone. There are many other travel paths possible, including reflections and refractions from deeper layers.

Two types of travel paths are needed to determine depths, beneath the shot points, to contrasting geologic layers:

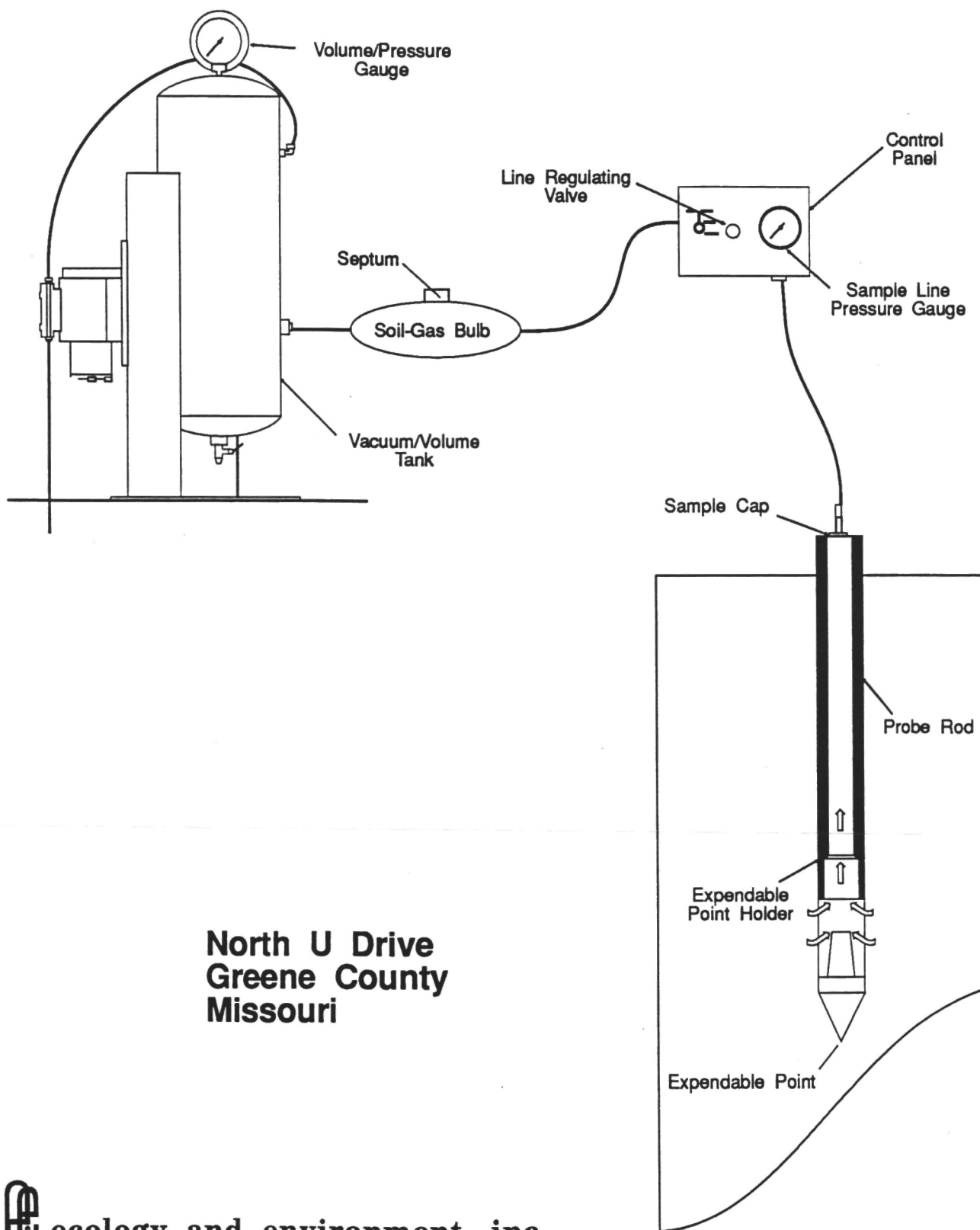
- o the direct arrivals traveling exclusively in the near surface layer, and
- o refractions from deeper layers.

The seismic energy initially received at each geophone is called the "1st break", regardless of its travel path.

Since the energy traveling along a geological interface (refractor) propagates at the faster velocity ( $V_2$ ) it will eventually arrive at a geophone before a direct arrival, which travels exclusively in the slower velocity layer. This is shown in Figure 2.4-2 (b) where a line connecting the "1st breaks" for the direct arrivals would intercept a line along the refractors "1st breaks" at channel 7.

The digital processing of the raw seismic record (Figure 2.4-2 (a)) involves a windowed gain function which increases low amplitude events and decreases very high amplitude events. This facilitates the recognition of significant events and allows the operator to pick the travel times of the "1st breaks" from the record.

After the 1st break travel times for each channel, or geophone, are picked from the seismic record they can be plotted on a graph of shot-to-receiver distance versus travel time. The different slopes of straight line segments drawn through the data points represent different events (direct arrivals, refractor 1, refractor 2, etc.). Each slope is the inverse of the apparent velocity of seismic energy in that material.



**Figure 2.3-2: Soil-Gas Apparatus**

point remained at the bottom of the hole leaving a 6-inch long by 1-inch diameter chamber or void. This void in the soil allowed soil gas to be drawn into the soil-gas rod when a vacuum was applied to the top of the rod. The top of the rod was fitted with a sampling head which allowed the attachment of a vacuum line to the soil-gas rod. A vacuum gauge and sampling bulb were placed in-line between the sampling head and the vacuum pump. The vacuum gauge was attached between the sampling head and the sampling bulb, allowing constant monitoring of the sampling conditions. Prior to collecting a sample, three volumes of air were purged from the sampling system. Each soil-gas rod has an annular volume of approximately  $100\text{ cm}^3$ . Once the appropriate presampling volume was purged from the system, the sampling bulb stopcock on the vacuum pump side was closed. This initiated the sample-collection phase of the task. Sample collection continued until the volume of soil-gas drawn through the bulb totally displaced the volume of air previously contained in the system. A vacuum flow-rate of  $100\text{ ml/min.}$  was calibrated at each location with an in-line rotometer. As each Geoprobe rod's annular volume was  $100\text{ cm}^3$ , two rods put end-to-end to provide a sampling depth of five feet held  $200\text{ cm}^3$ , or ml. On the average, six minutes of purging displaced three volumes of the soil-gas apparatus. Another three minutes at the same  $100\text{ ml/min.}$  flow-rate assured representative soil-gas within the sample bulb. At this point the sampling bulb stopcock on the soil-gas rod side was closed. The vacuum pump was then stopped and the sampling bulb was delivered to FASP personnel for analysis. For any duplicate sample, a second sampling bulb was installed in the system and the sampling procedure was repeated, minus the initial purging phase.

Samples were analyzed within one hour, with some exceptions due to delivery and/or analysis problems. When the soil-gas holding time was exceeded the analytical results were not invalidated, rather they were flagged as an estimated value.

The final number of sampling points around a particular potential source depended on the size of the potential source and the degree of detected contamination. Initially all sources except the Montgomery Metal Craft tank yard were considered the same size, with the tank yard

considered twice the size of the other eight potential sources. However, field analysis of the soil-gas warranted collection of more than the initial five samples taken around the eight smaller locations, as described below. The centroid of each potential source was identified and sampled. An attempt to establish additional sampling nodes approximately 100 feet north, south, east, and west was made, however the actual spacing had to accommodate soil lithology and topography as shown on Figure 2.3-1.

The soil-gas survey produced a total of 87 samples, including duplicate samples, equipment blanks and ambient air blanks. If no volatile organics were detected in the soil gas around a sample point it was discounted as a potential source. After the initial sampling effort, detections were plotted on a site map and an expanded sampling grid was established to aid in the delineation of the areal extent of the soil-gas plume for each individual source. Quality Assurance and Quality Control (QA/QC) were provided by the collection of one sample duplicate, laboratory sample duplicates, field sampling equipment blanks, and ambient air blanks. The ratio of samples to duplicates was approximately 10:1 for this site. Equipment blanks were run on all decontaminated sample bulbs and on decontaminated soil-gas rods used on sampling locations that showed contamination.

The duration of this sampling effort was contingent on the relative ease of installing soil-gas rods, sample extraction, and the presence or absence of detectable contaminants in the soil gas. Although E & E estimated one sampling team would be able to sample 20 locations per day, only an average of 12 samples per day were collected due to soil lithology and topography. Additionally, a replacement for the initial GC instrument was necessary, delaying the soil-gas survey start-up date three days.

#### Soil-Gas Sampling Collection Method

Soil-gas sampling attempted to identify the existence of a soil-gas plume within the vadose zone around each potential source and quantify its relative intensity. Due to the number of potential sources, and the

similarity of the proposed soil-gas sampling techniques at each location, a single methodology was detailed in the work plan for this RI/FS. Slight variations of this methodology were implemented during field activities to accommodate field conditions. These variations involving a number of sampling points are described in the specific field activities for each potential source.

#### Soil-Gas Sampling Analysis Method

An SRI 8610 Gas Chromatograph (GC) equipped with a capillary column and an HNu Photoionization Detector (PID) was used to quickly identify compounds in the soil-gas samples. A Spectraphysics SP4200 Integrator was used for data acquisition. Established E & E Field Analytical Screening Program (FASP) protocols were used for the analytical portion of this survey. Calibration standards were prepared in solvent (methanol) to a known concentration, allowing the total weight injected, in nanograms, to be calculated. Samples were collected in 250 mL glass bulbs with polymer stopcocks and standard septa. Aliquots of 1 mL were withdrawn from the bulb using a gas-tight syringe and injected into the instrument for analysis. Blanks and duplicates (laboratory and field) were analyzed to check for contamination and for precision of the field and laboratory efforts providing good QA/QC.

The analytes of interest were benzene, toluene, ethylbenzene, o-xylene, trichloroethylene (TCE), and tetrachloroethylene (PCE). Also available for conclusive identification were methyl tert-butyl ether (MTBE) and several halogenated compounds (dichloroethene (DCE), trichloroethane (TCA), and others).

A three-point calibration was performed using the analytes in methanol. The relative standard deviation calculated showed that TCE and PCE did not yield a linear response due to solvent contamination and/or detector characteristics. Therefore, results for TCE and PCE were flagged ("J") as estimated. The benzene/toluene/ethylbenzene/xylene (BTEX) compounds gave a linear response during calibration. Methyl tert-butyl ether (MTBE) co-eluted with the solvents used for calibration and so a quantitative assessment could not be made. Headspace standards were

injected in order to provide a qualitative (tentative) identification of peaks in some samples. This identification is obviously subject to interference.

Quantitation limits for all analytes were determined to be 1 ng/mL. Unidentified compounds were quantitated using the integrator response (area) obtained and the response factor calculated for benzene to give an estimated quantity for non-target compounds.

A stock standard aliquot was spiked into a sample bulb and analyzed after evaporation of the spike. This allowed the expected retention time shift for gaseous-versus-liquid compounds to be accounted for during sample assessment. In relative terms, a decreased response for the heavier analytes (ethylbenzene and o-xylene) was noted. This would be expected due to their lower vapor pressure.

On three occasions during the field effort, an external radio source introduced noise interference to the chromatograms obtained during analysis. This noise was unpredictable and unavoidable, and the source could not be identified. A similar effect was observed on other site investigations (which utilized GCs) when a walkie-talkie radio was used to transmit while in close proximity to the instrument/integrator. The effect of this noise was to preclude identification of trace level contaminants in samples, if present. However, significant contamination was detectable above the noise, as when standards were analyzed. Useful information was still obtained from the analysis.

The work plan stated that samples not analyzed within one hour would have invalidated results. However, it should be noted that the soil-gas survey is a screening technique used to present relative indications of contamination and tentative identifications, where possible. In addition, a sample showing moderate contamination was held overnight at room temperature, not exposed to sunlight, and reanalyzed the following day as a test. It yielded comparable results to those obtained from the original analysis. In a few instances, samples were not analyzed within one hour due to delivery and/or analysis problems. These results were flagged ("J") as estimated and should be considered useful for the purposes of the study.

### Soil-Gas Sampling

The sample series for this soil-gas activity was MG2016-SGS. Figure 2.3-1 depicts sampling locations. The soil-gas field analytical results are discussed in Section 4.

### Montgomery Metal Craft Tank Yard

The soil-gas sampling at the Montgomery Metal Craft tank yard was conducted on October 13, 14, and 19, 1990. Sixteen soil-gas samples were taken within the tank yard area. Sample numbers were 001 through 014, and 086 and 087. One duplicate sample (004) and two ambient air blank samples (002 and 087) were collected for QA/QC.

### Former Five Gables Service Station

The soil-gas sampling at the former Five Gables service station (Bolivar Road Bookstore) was conducted on October 14, 1990. Seven soil-gas samples were taken within the bookstore property. Sample numbers were 015 through 021. One field equipment (020) and one ambient air (021) blank sample were collected for QA/QC purposes.

### Mobile Gardens Trailer Park Sinkhole

The soil-gas sampling at the Mobile Gardens Trailer Park sinkhole was conducted on October 14 and 15, 1990. Six soil-gas samples were taken within the sinkhole area. Sample numbers were 022 through 027. No field equipment or ambient air blank samples were collected at this location.

### Montgomery Metal Craft Plant

The soil-gas sampling at the Montgomery Metal Craft plant was conducted on October 15, 1990. Eight soil-gas samples were taken around the manufacturing plant. Sample numbers were 028 through 035. One field equipment blank sample (034) was collected for QA/QC purposes.

#### Coble Sinkhole

The soil-gas sampling at the Coble sinkhole was conducted on October 15, 1990. Five soil-gas samples were taken within the sinkhole. Sample numbers were 036 through 040. No field equipment blank sample was collected at this location.

#### Degraffenreid Sinkhole

The soil-gas sampling at the Degraffenreid sinkhole was conducted on October 16, 1990. Six soil-gas samples were taken within the sinkhole area. Sample numbers were 041 through 046. No field equipment or ambient air blank samples were collected here.

#### Parrish Drive and Stage Coach Drive

The soil-gas sampling along Parrish Drive and Stage Coach Drive was conducted on October 16 and 19, 1990. Nine soil-gas samples were taken along these two roads. Sample numbers were 047 through 049, and 079 through 084. One field equipment (080) and two ambient air (048 and 081) blank samples (048 and 081) were collected for QA/QC.

#### Frazier Brothers Construction Company

The soil-gas sampling at the Frazier Brothers Construction Company was conducted on October 17 and 18, 1990. Ten soil-gas samples were collected on the company's property. Sample numbers were 050 through 059. No field equipment or ambient air blank samples were collected at this location.

#### Former Curtis Service Station

The soil-gas sampling at the former Curtis service station was conducted on October 18 and 19, 1990. Fourteen soil-gas samples were obtained at the location, owned by Frazier Brothers Construction Company. Sample numbers were 060 through 072, and 085. No field equipment or ambient air blank samples were collected at this location.

#### Former Derby Service Station

The soil-gas sampling at the former Derby service station was conducted on October 19, 1990. Six soil-gas samples were collected at this former gasoline service station. Sample numbers were 073 through 078. No field equipment or ambient air blank samples were collected at this location.

#### Decontamination of Soil-Gas Equipment

After each sample collection the soil gas rods were withdrawn from the soil and decontaminated. This procedure consisted of external cleaning of the rods and subsequent heating to drive off possible contamination by volatile organic compounds. A portable heater with 150,000 BTU capacity was used to heat the rods for more than 20 minutes during each decontamination procedures. The external cleaning was accomplished by a solution of Alconox and deionized water wash. Equipment blanks were collected to validate the decontamination procedures. Sampling bulbs were also decontaminated with heat and checked in a similar manner. A portable vacuum pump and a hair dryer were used for air and volatile contaminants extraction. Sampling bulbs were analyzed after decontamination to assure the absence of contaminants in the bulbs.

#### Investigation-Derived Waste

The work associated with Phase 1 was performed in level D protection. However, small quantities of disposed Personnel Protective Clothing (PPC) were generated. Any PPC determined not to be contaminated was disposed of in a double-lined plastic bag and taken to the local municipal landfill. Any PPC determined to be potentially contaminated was placed into a 55-gallon DOT-approved drum with a double-plastic liner. The drums were labeled and placed in an on-site secure area until disposition can be determined by MDNR.

### Deviation from the Work Plan

Regarding the soil-gas activities, all three guidance documents state that duplicate soil-gas samples were to be collected as part of the QA procedures. However, because an air sample cannot feasibly be homogenized and separated into different containers under field conditions, soil-gas "duplicates" were developed as an alternate in the laboratory; that is, laboratory splits were prepared from a single field sample. This type of QA protocol is useful in estimating the analytical precision of any given laboratory procedure.

## 2.4 GEOLOGICAL INVESTIGATIONS

Three geophysical methods, seismic refraction, resistivity, and very low frequency (VLF) electromagnetics were used to characterize shallow geology at the North U Drive study area. Specifically, these techniques were employed to help create a map of the competent bedrock surface beneath the study area, and also identify potential subsurface conduits (faults, fractures, etc.) for contaminant migration. In this section, each of these geophysical methods will be introduced with a brief explanation of the principals involved, followed by the methods and procedures used at this site. The survey results are addressed and interpreted in Section 3.3.

### 2.4.1 Seismic Refraction Survey

The seismic method of subsurface exploration utilizes the basic physics of wave propagation, reflection and refraction in media exhibiting different physical properties. There are three major system components needed for the acquisition of seismic data:

- o SHOT. This is the energy source that generates seismic (or acoustic) waves through the subsurface;
- o RECEIVER. This instrument, usually called a geophone, converts the ground motion, caused by seismic waves, into a proportional electrical signal; and
- o RECORDER. This electrical instrument converts and stores the signals from the receiver into positive or negative integers of

varying amplitudes that correlate with the ground motion intensity and direction (up or down) at the receiver. The recorder continuously samples each receiver at a discrete time interval until a user-specified total time initiated at the shot is reached. The completed result is a seismic record.

An idealized layout for a seismic survey is shown in Figure 2.4-1. This figure also illustrates selected travel paths (raypaths) from a shot to a geophone. There are many other travel paths possible, including reflections and refractions from deeper layers.

Two types of travel paths are needed to determine depths, beneath the shot points, to contrasting geologic layers:

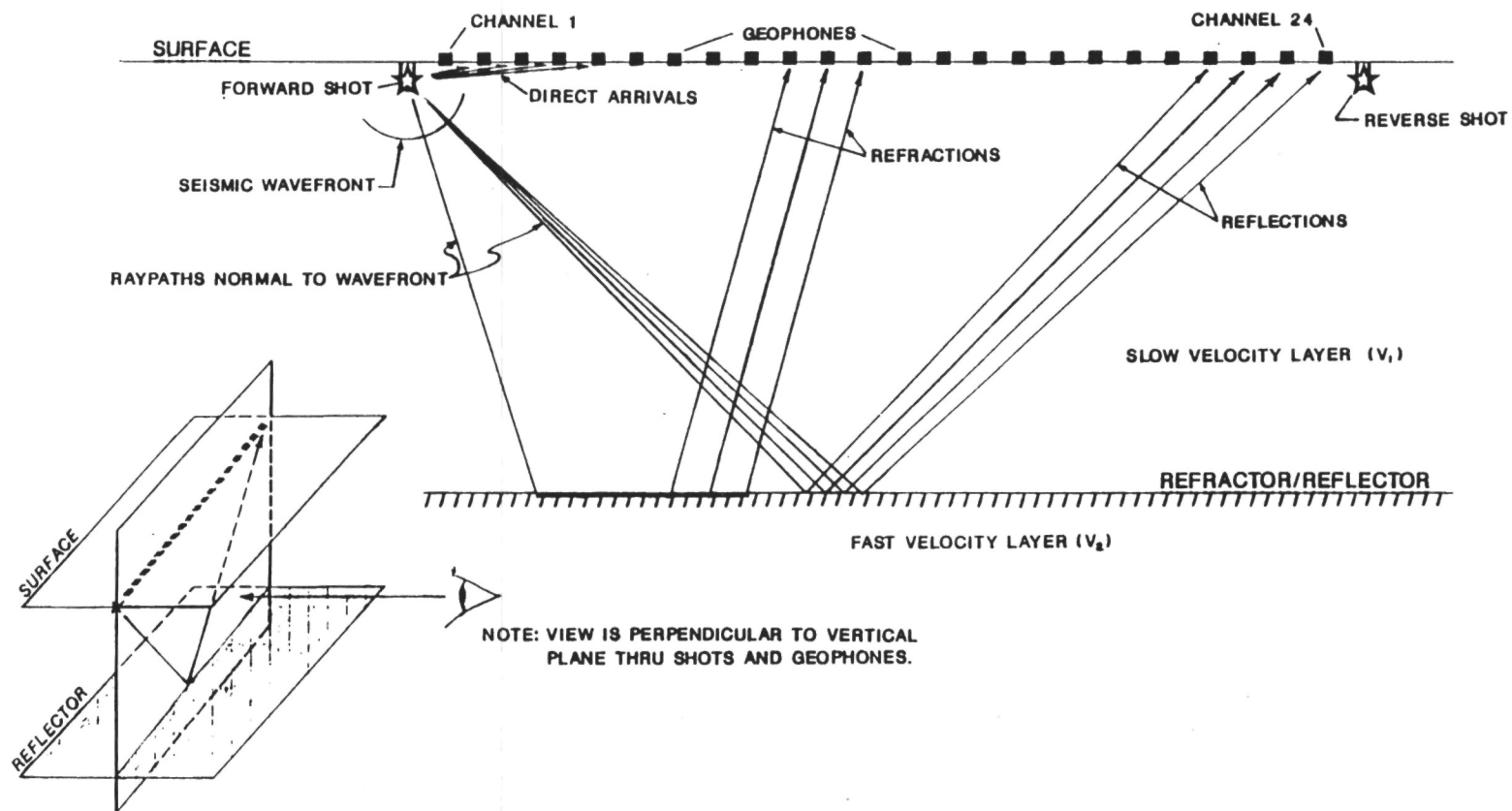
- o the direct arrivals traveling exclusively in the near surface layer, and
- o refractions from deeper layers.

The seismic energy initially received at each geophone is called the "1st break", regardless of its travel path.

Since the energy traveling along a geological interface (refractor) propagates at the faster velocity ( $V_2$ ) it will eventually arrive at a geophone before a direct arrival, which travels exclusively in the slower velocity layer. This is shown in Figure 2.4-2 (b) where a line connecting the "1st breaks" for the direct arrivals would intercept a line along the refractors "1st breaks" at channel 7.

The digital processing of the raw seismic record (Figure 2.4-2 (a)) involves a windowed gain function which increases low amplitude events and decreases very high amplitude events. This facilitates the recognition of significant events and allows the operator to pick the travel times of the "1st breaks" from the record.

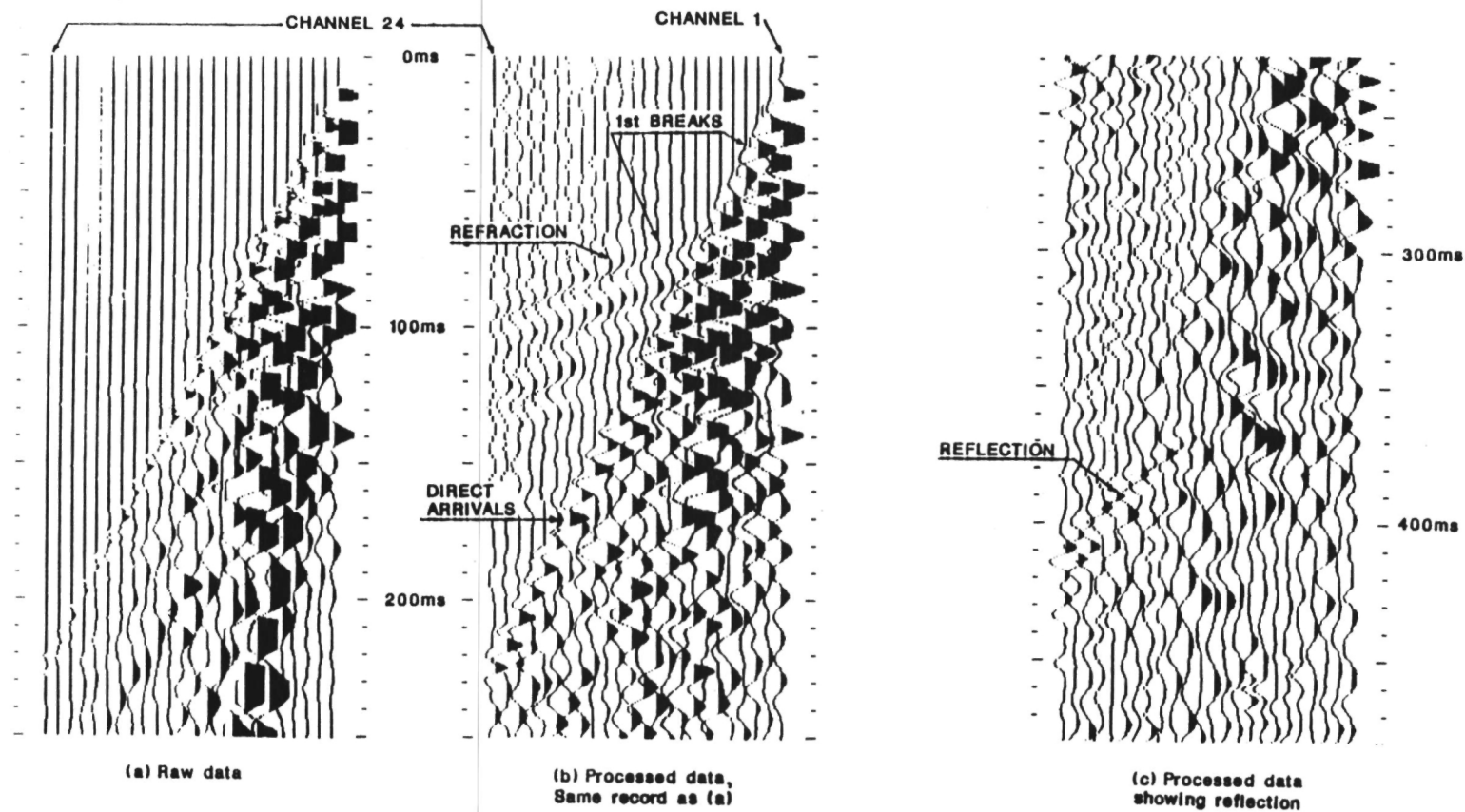
After the 1st break travel times for each channel, or geophone, are picked from the seismic record they can be plotted on a graph of shot-to-receiver distance versus travel time. The different slopes of straight line segments drawn through the data points represent different events (direct arrivals, refractor 1, refractor 2, etc.). Each slope is the inverse of the apparent velocity of seismic energy in that material.



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Figure 2.4-1: GENERALIZED SEISMIC LINE LAYOUT AND RAYPATH CROSS-SECTION



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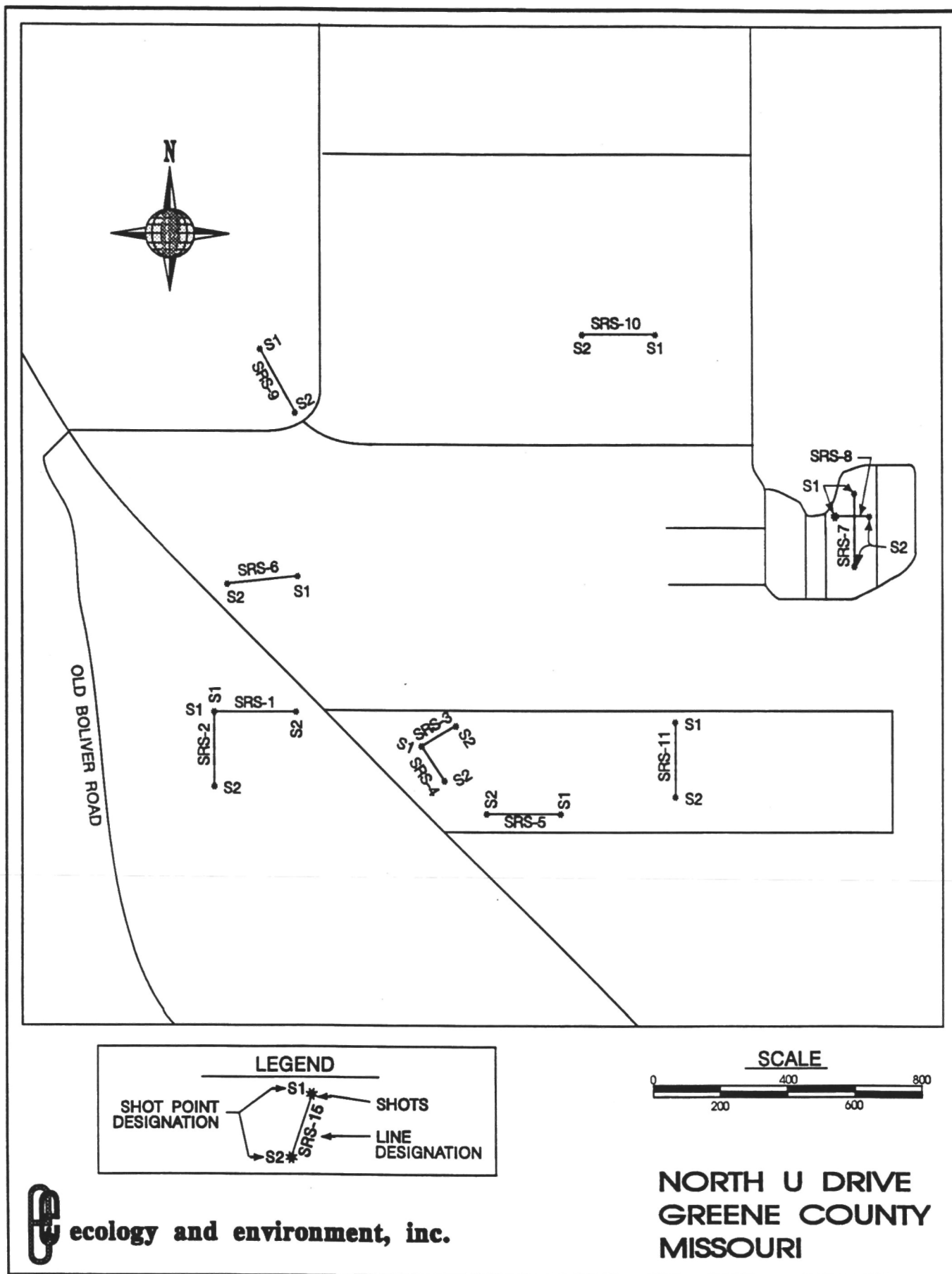
Figure 2.4-2: EXAMPLE OF SEISMIC DATA RECORDS

This velocity is an apparent velocity, except in a rare case where the seismic line and refractor are parallel (relative dip = 0 degrees), as shown in Figure 2.4-1. To determine the true velocity of a refractor, a reverse shot (from the opposite end of the seismic line) must be recorded. The 1st break travel times are picked from the reverse record and plotted on the same graph (and in the same manner) as the forward shot, with the reverse shot zero-offset distance at the opposite end of the x-axis. The true refractor velocity is the harmonic mean of the forward and reverse apparent velocities, multiplied by the cosine of the dip angle. The same lines from which velocities are derived are extended back to the zero-offset distance for that shot. The time intercept for that refractor is at the intersection of this line and the time axis at the zero-offset distance.

Deeper layers with faster velocities may also yield 1st break refractions. The velocities and time intercepts for these later refractors are determined in the same manner described above.

The depth to each layer beneath both shots can be calculated by utilizing Snell's Law of Refraction, trigonometric functions, the true velocities for each layer, and the time intercepts from each shot. However, it should be noted that the Time Intercept Method (the method discussed above) assumes that each succeeding layer has a faster velocity than the overlying layer(s). If this assumption is not valid, the refraction method will not yield accurate information. Also, the accurate plotting of straight line segments through a set of data points associated with a single refractor becomes more difficult as the refractor surface becomes more irregular (non-planar). The limitations caused by non-planar bedrock surfaces were often apparent in the data collected at the North U Drive Study Area, as discussed in Section 3.3.

Data from 11 seismic lines were acquired in the North U Drive Study Area. Figure 2.4-3 shows the locations of all 11 seismic lines. Each line consisted of a forward and reverse shot separated by distances ranging from 90 to 240 feet. The only deviation from the work plan, regarding the seismic refraction survey, was the use of a 24-channel (Bison Instruments model 8024) rather than a 12-channel seismograph.



Prepared By: L.J.Baer

January, 1991

Figure 2.4-3: SEISMIC SURVEY LOCATION MAP

Lines SRS-3 and SRS-4 constituted a single layout with channels 1 through 12 (line 3) perpendicular to channels 13 through 24 (line 4). Line SRS-8 was also a 12 channel line; all remaining lines were 24 channels.

The procedures for acquiring seismic refraction data for a given line involved the following steps:

- o Laying out the seismic cables, "planting" the geophones in the ground, and connecting the geophone to the recorder;
- o Setting the recorder gains for each geophone using the instruments auto-gain function (this is not the digital processed gain previously mentioned);
- o Generating the seismic energy at the shot location by striking a metal plate with a 12-pound sledge hammer. At each shot point the data was "stacked" by striking the plate several times, thus increasing the signal to noise ratio for that record. At the moment of impact (time zero), a trigger attached to the sledge hammer sends a signal to the recorder. At that point, the recorder begins collecting information from the geophones;
- o Setting up and recording the reverse shot; and
- o Tying the seismic line to cultural features (fences, roads, etc.) for subsequent mapping and determining relative shot elevations using a hand level and 6-foot folding rule.

All shots were offset 5 feet from the nearest geophone, and in-line with the entire geophone array. The geophone spacing along line SRS-1 was 10 feet. Subsequent lines (SRS-2 through SRS-11) had spacings of 5 feet between the first 3 to 7 geophones (nearest the shot point), with 10 foot spacings between remaining geophones. This procedure would create enough data density on the time-distance graph to accurately define apparent, rapidly changing near-surface layers. This situation, as it relates to subsurface geology, is further addressed in Section 3.3.

#### 2.4.2 Resistivity Survey

The resistivity technique is applied by introducing an electrical current (I) into the ground through a pair of electrodes implanted at the surface. The voltage potential (V) is concurrently measured between a second pair of electrodes, also implanted at the surface. Resistance (R) is then calculated (using Ohm's law,  $V = IR$ ) and displayed by the survey instrument. This value and the spatial arrangement of the electrodes can then be considered to determine the apparent resistivity ( $\rho_a$ ). In general, resistivity is an intrinsic property of a material and is equal to the measured resistance multiplied by a geometric factor. For example, in the case of a wire in a simple DC circuit, the resistivity equals the voltage drop (V) across a length (L) of the wire divided by the current (I), times the cross-sectional area (A) of the wire divided by L, or:

$$\rho = \frac{V}{I} \frac{A}{L}$$

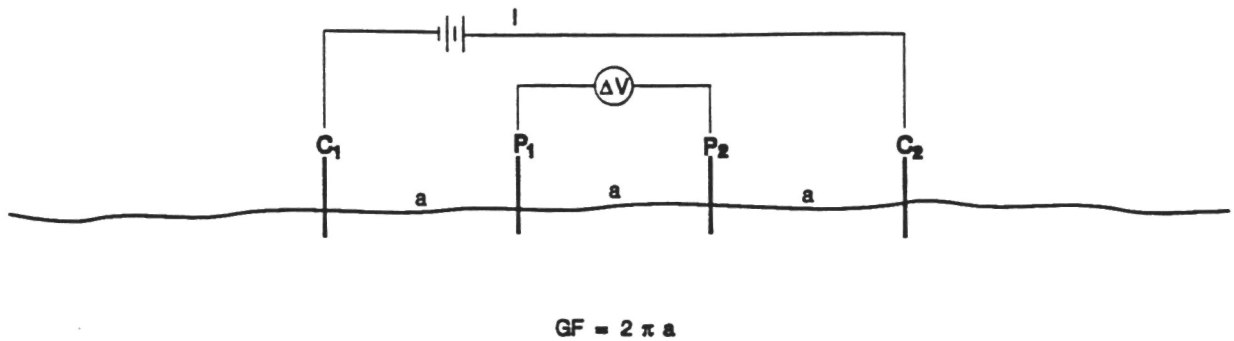
where resistance,  $R = V/I$  and  $A/L$  is the geometric factor for a prismatic solid.

The geometric factor for resistivity surveys are more complicated since an infinite, homogenous half-space (the earth model) replaces the finite wire in the D.C. circuit example above. In addition, there are numerous configurations for the placement of electrodes, resulting in different geometric factors. Figure 2.4-4 shows three commonly used electrode configurations, Wenner, Schlumberger and Dipole-Dipole, and their geometric factors (GF).

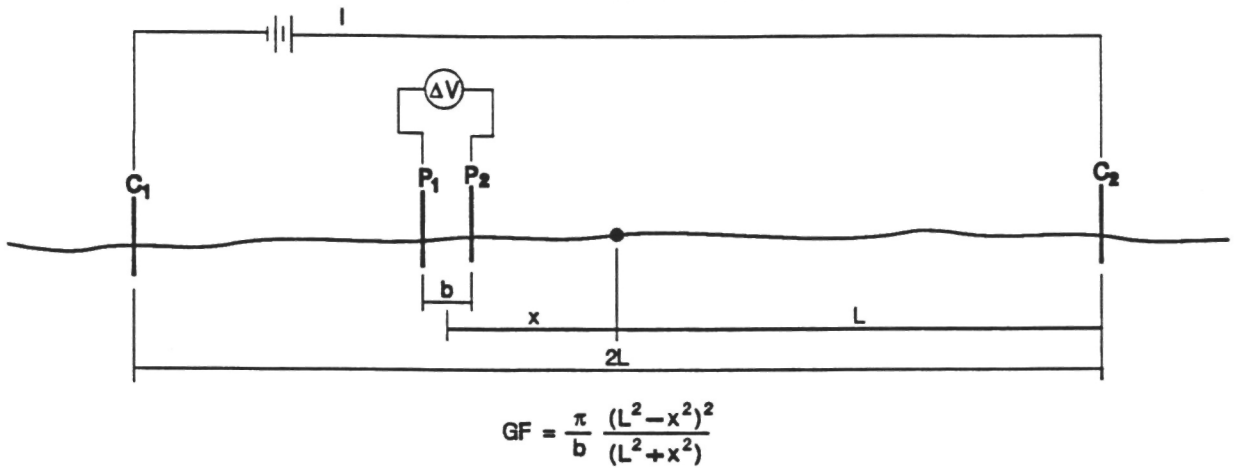
Resistivity is a function of the type of soil or rock, its porosity, permeability, and type of pore fluids present. Since actual field measurements of a resistivity survey are made on the surface of a heterogeneous earth, values obtained are called "apparent resistivity" to distinguish it from the true resistivity of any single point within the subsurface study.

For example: a single sand grain would have the same resistivity in a dry sand as in a wet sand. However, an apparent resistivity value for

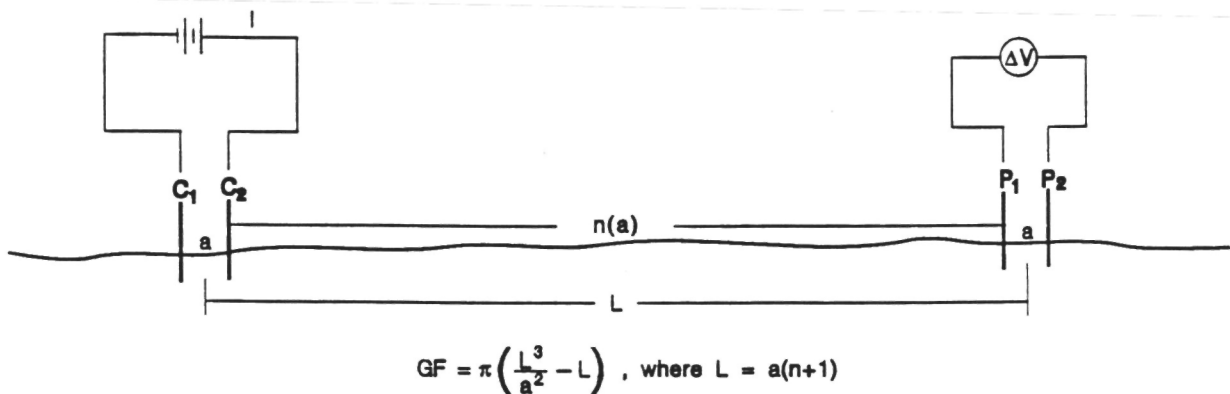
### WENNER ARRAY



### SCHLUMBERGER ARRAY



### DIPOLE-DIPOLE ARRAY



NOTE: n must be an interger equal to the distance from C<sub>2</sub> to P<sub>1</sub> divided by a.

GF = GEOMETRIC FACTOR  
 APPARENT RESISTIVITY =  $\rho_a = GF \left( \frac{\Delta V}{I} \right)$

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**Figure 2.4.4: COMMON RESISTIVITY SURVEY ELECTRODE SPREADS**

the wet sand would be much lower than that for the dry sand. In addition, intermediate values of apparent resistivity would be seen in a less than 100% saturated wet sand.

There are three general methods to acquire of field resistivity data:

- o Sounding - Also called "electric drilling," this method yields changes in resistivity beneath a surface point. The method involves increasing electrode spacing, thereby increasing the investigation depth beneath a single point. This data can be interpreted to get estimates of the depths and lithologies of the underlying geoelectric layers;
- o Profiling - Single resistivity measurements are taken at different stations (in a grid) using the same electrode spacing. This method yields lateral changes in resistivity to a certain depth; and
- o Azimuthal - Keeping the electrodes at a set distance (constant penetration depth) the resistivity line is rotated about one end, taking measurements every few degrees, until a full circle has been covered. The interpretation of this data yields directional (azimuthal) information of linear resistivity anomalies, such as fracture zones.

A dipole-dipole electrode array was chosen for its ability to yield vertical and lateral resistivity data at a much faster rate than would be possible through separate sounding and profiling surveys. Illustrations (a) through (c) in Figure 2.4-5 show the dipole-dipole electrode configurations for three separate readings on a resistivity survey line. The first of these, (a), shows the usual set up for taking the first reading on a line. The spacings between the electrodes, called the "a" spacing, are equal. The designation for this reading would be "station  $0 + 12.5, n = 1$ ," where "station" is the location of the current dipole (midway between the current electrodes,  $C_1$  and  $C_2$ ) and "n" is an integer equal to the distance between the closest current and potential electrodes ( $C_2$  and  $P_1$ ) divided by the "a" spacing.

Illustration (b) shows the electrode configuration for the next reading along the line, designated "station  $0 + 12.5, n = 2$ ." The potential electrodes would continue to move up, with the current elec-

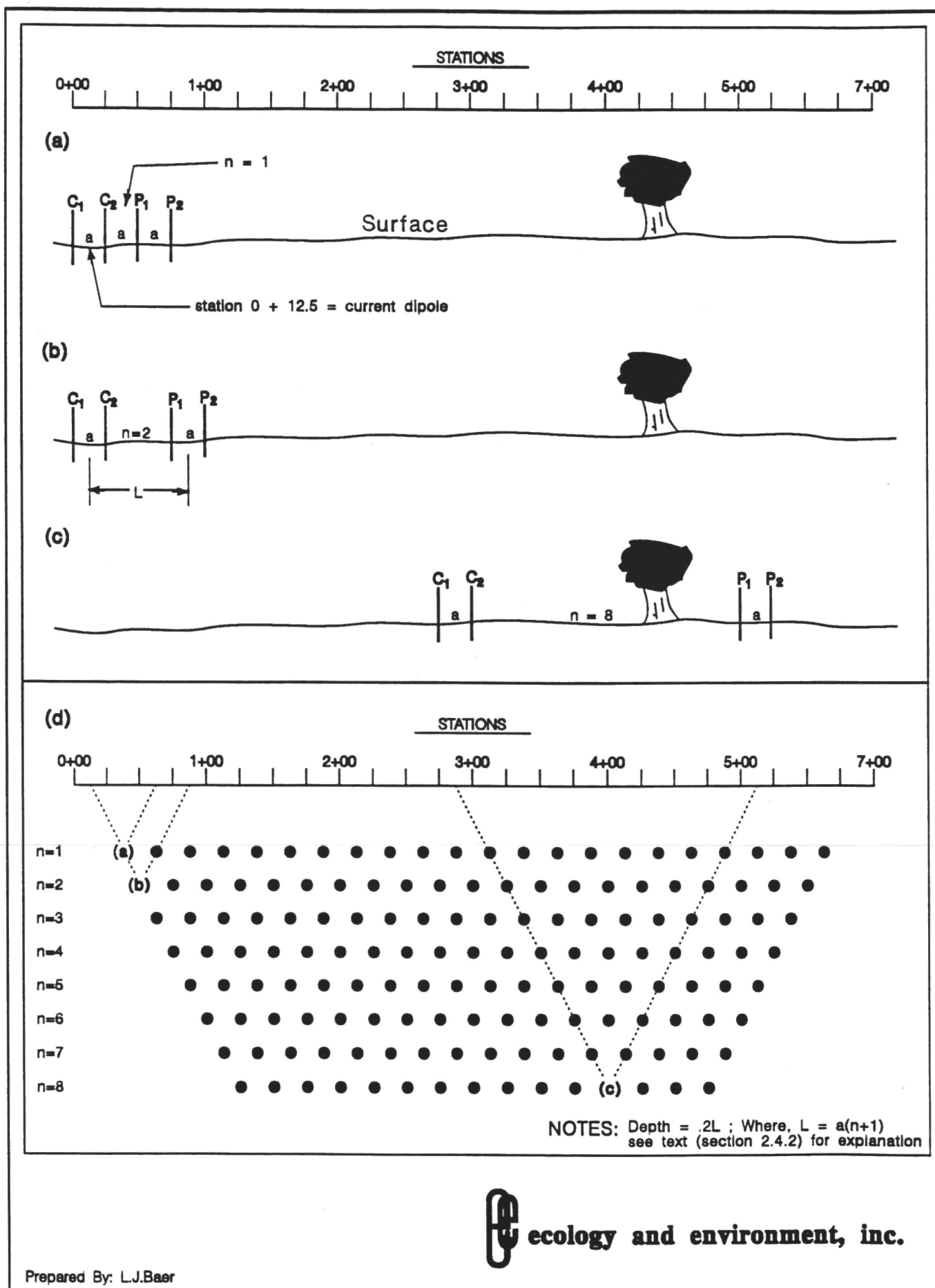


Figure 2.4.5: ELEMENTS OF DIPOLE-DIPOLE RESISTIVITY SURVEY

trodes remaining stationary until  $n$  reaches a designated maximum ( $n = \text{max}$ ). The current electrodes are then moved up one "a" spacing and a new set of readings are recorded for  $n = 1$  up to  $n = \text{max}$ . Illustration (c) shows a later electrode configuration for the line, its designation being "station 2 + 82.5,  $n = 8$ ".

The reduction of the resistivity survey data begins with calculating the apparent resistivity values. This is done by multiplying the instrument readings ( $R$ ) by the geometric factor for that  $n$  value. The apparent resistivity values can then be plotted to generate a pseudo cross-section, as illustrated in Figure 2.4-5 (d). The value for a specific electrode configuration is located beneath the midpoint between the current and potential dipoles at the corresponding  $n$  layer. An approximate depth can be assigned to the  $n$  layers, as follows:

$$\text{Depth} = .2 L$$
$$\text{where, } L = a (n + 1)$$

Eleven resistivity lines were completed in the North U Drive study area, as shown in Figure 2.4-6. The locations were plotted on a large scale topographic map so coordinates and elevations along the lines could be determined.

Various types of contour maps could be generated from the complete data set including; iso-resistivity contours at either a specific depth (beneath the surface station) or subsurface elevation; subsurface topography of a specified apparent resistivity; or depth contours to a specified resistivity.

As further discussed in Section 3.3, the pseudo cross-sections and various contour maps were then included in the integrated interpretation of the local subsurface geology. All resistivity data is included in Appendix B-2.

#### 2.4.3 Very Low Frequency Electro Magnetism

The very low frequency (VLF) electromagnetic method utilizes a powerful (300-1000 kilowatt) signal, emitted by a distant transmitter in the 10 to 30 KHz range. The primary magnetic field lines generated by a

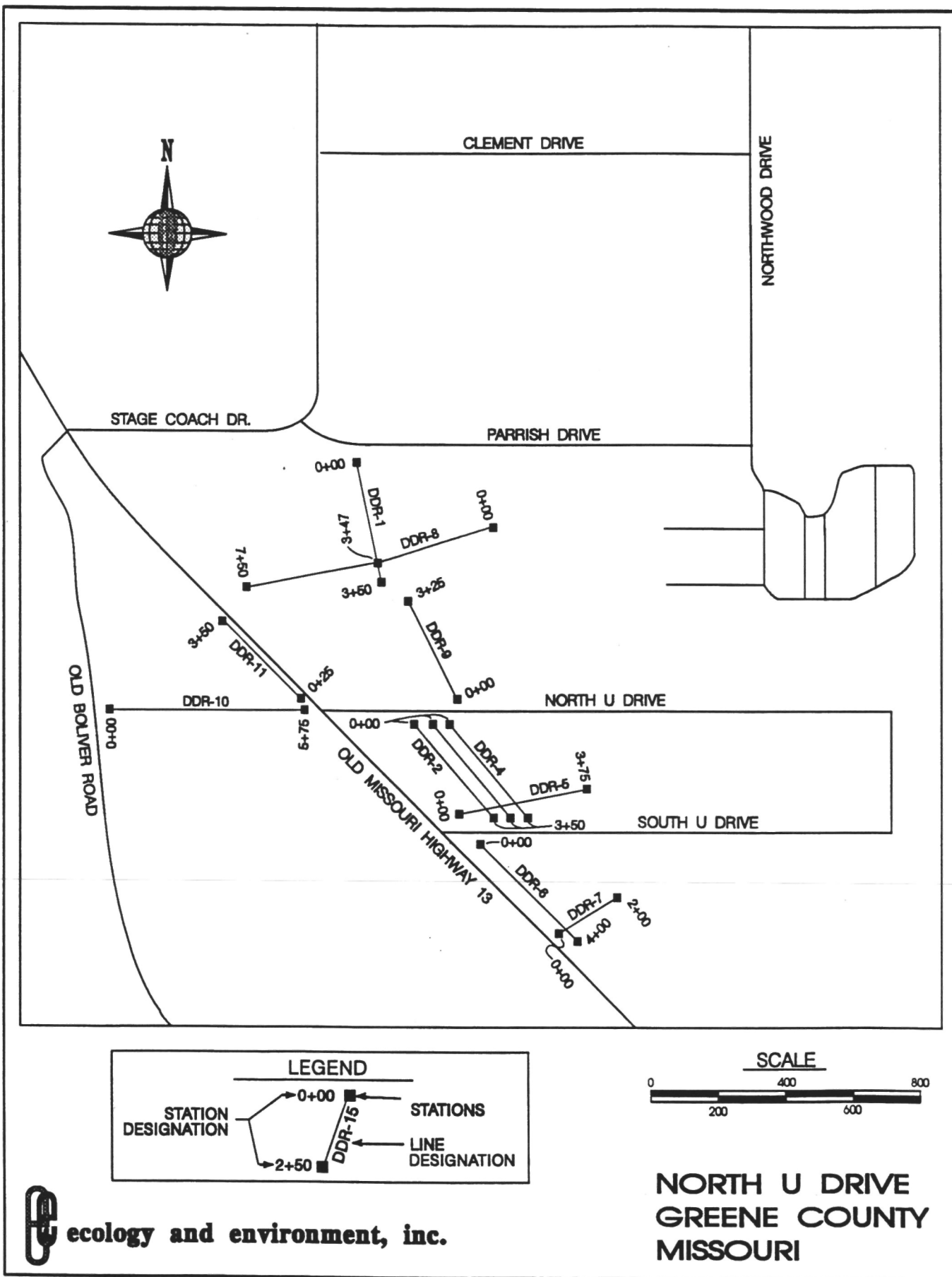


Figure 2.4-6: RESISTIVITY SURVEY LOCATION MAP

VLF signal can be considered horizontal and planer due to the large wavelengths associated with these signals (up to several kilometers). If an elongated, steeply dipping conductor is oriented roughly perpendicular to the primary field, a secondary field with a vertical component will be induced. A VLF surveying instrument measures the horizontal and vertical components of the electric field along the ground surface of a given point and records their ratio as a percentage. In the absence of an appropriate subsurface conductor, only the horizontal primary field yields a response; the reading is zero. It should be noted that a horizontal conductive layer would also yield a zero reading and, therefore, could not be identified by the VLF method. The depth of penetration for a particular VLF investigation is a function of the primary field frequency and the subsurface resistivities associated with the study area. Resistivities throughout the North U Drive vicinity averaged approximately 200 ohm-feet, and the primary field frequency was about 20 KHz. Considering these parameters, an estimated effective penetration depth of 50.3 feet was calculated. Actual depths of penetration at given locations will vary, in some cases significantly, from this estimate.

The VLF instrument used at the study area was an ABEM WADI. The WADI consists of an antenna unit, an analog signal-processing unit, and a computer unit. Since the entire configuration is worn on a belt, data can often be acquired by one person.

The VLF survey was initiated at the sinkhole behind the Coble property (lines 0020E, 0040E and 0060E, Figure 2.4-7), expanding south onto the mobile home court, and west down Parrish Drive (lines 1502E through 1515E, non-inclusive). Two lines (1516E and 1517E) were run to the west and north of Parrish. Additional VLF surveying was conducted at the former Curtis service station. Profiles on this latter property were spaced 25 feet apart and readings were recorded every 12.5 feet along each transect. This was the same grid constructed for the terrain conductivity and magnetic field surveys, discussed in Section 2.2.

Two profiles (0000E and 0100E) were also run outside of the study area, over a limestone outcrop exposed along a highway roadcut. The

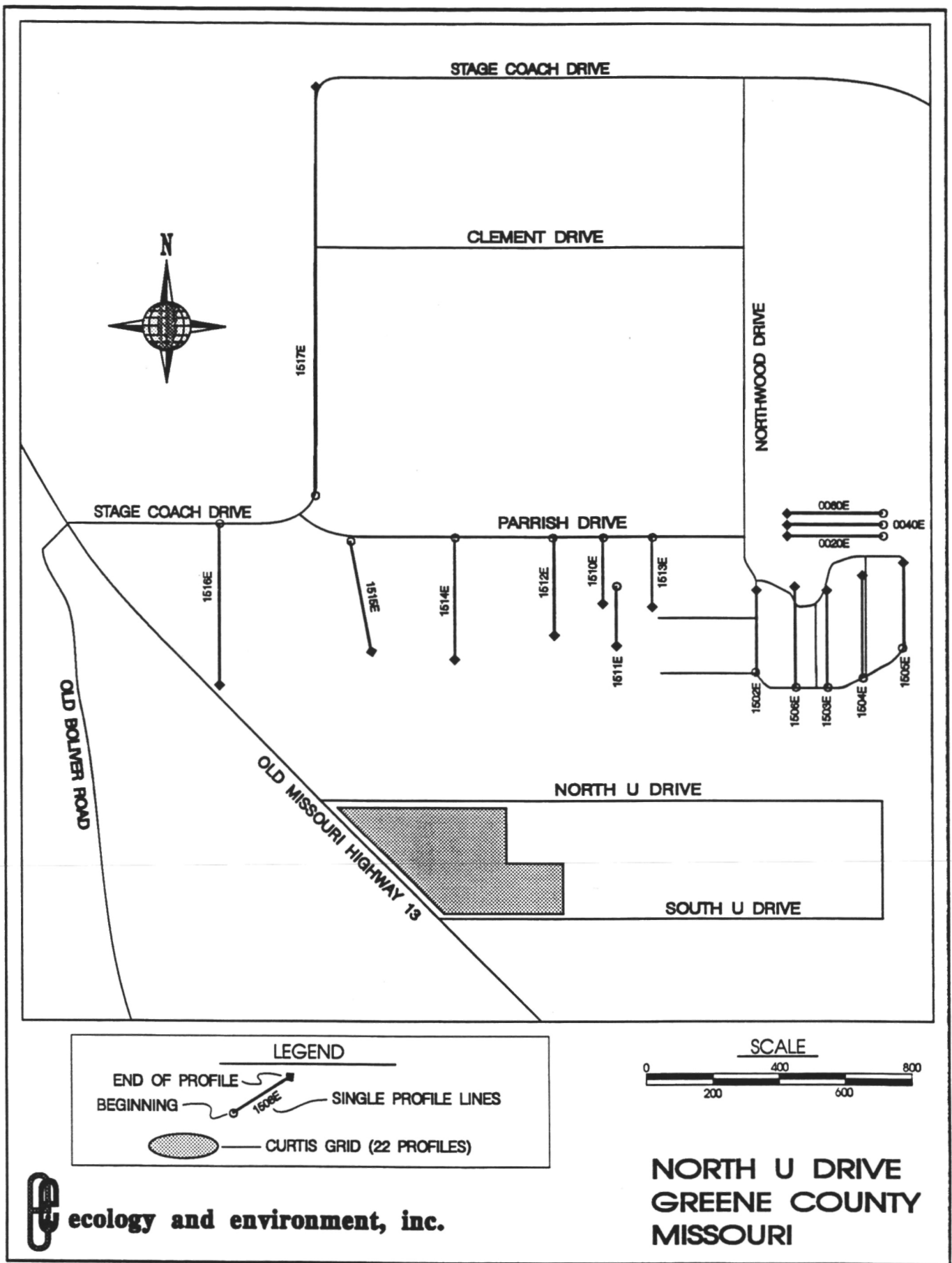


Figure 2.4-7: VLF SURVEY LOCATION MAP

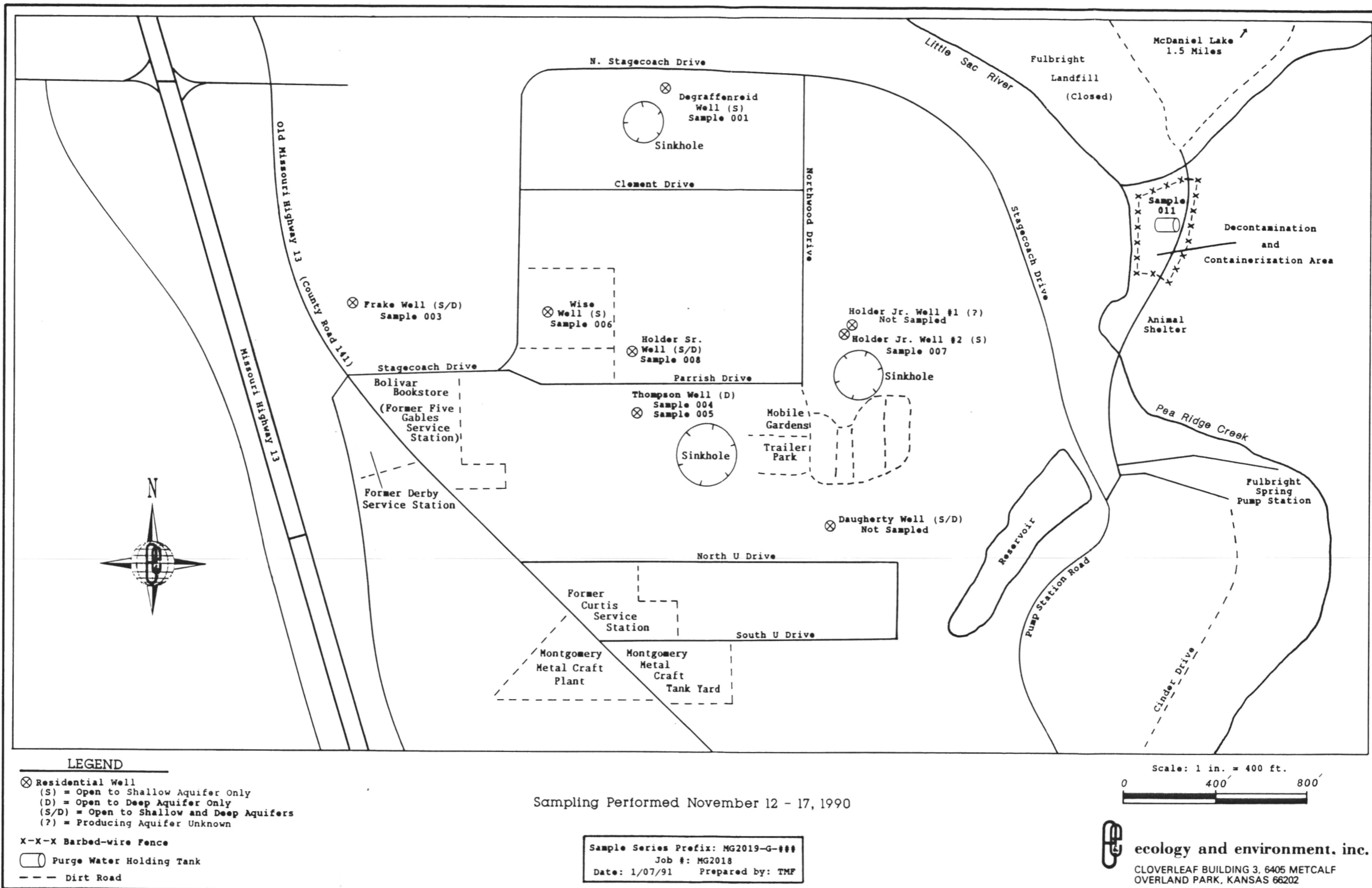
object of this test was to see if zones between bedrock pinnacles might be represented by VLF anomalies.

Data was downloaded from the ABEM WADI to a personal computer and saved on a floppy disk. The ABEM software SECTOR was then used to generate profiles and pseudo cross-sections from the data. Display types are further addressed in Section 3.3 and all VLF data is included in Appendix B-3.

## 2.5 GROUNDWATER INVESTIGATION

During the week of November 18-24, 1990, E & E performed a limited groundwater investigation in the study area. Information obtained during the background investigation indicated that seven residential wells in the North U Drive area remained open subsequent to a directive which called for the plugging of all contaminated or endangered wells in the area. This directive was administered jointly by the MDNR and EPA in 1985. The remaining open wells were sampled in this Phase 1 investigation to obtain up-to-date information on the levels and areal extent of volatile organic contamination in the groundwater. Also, because no analytical parameters other than volatile organics had ever been tested for in previous rounds of sampling, the realm of parameters was expanded to include semi-volatiles (BNAs), total metals, dissolved metals, cyanide, and pesticides. It was determined that a comprehensive analysis of this sort would not only uncover any additional health risks associated with this site, but also provide clues as to the potential source(s) of the contamination.

One additional open well was identified during the investigation, bringing the total number of open wells to eight. This additional well was actually located on the same property as a previously confirmed open well, and was apparently open to the same aquifer based upon a comparison of water level measurements. In light of this fact, and considering that the two open wells were approximately 20 feet apart, only one of these wells was sampled. The locations of all open wells in the study area, as can best be determined to date, are illustrated in Figure 2.5-1.



### 2.5.1 Well Purging

Prior to sampling each well, water levels were measured using an electronic water level indicator. These measurements were collected so that purge volumes could be calculated. In most cases, well depth information was obtained from the site file information or directly from the well owners. For one well, where depth information was not available, this data was obtained by lowering the water level tape to the bottom of the well.

With the depth and water level information, the static water volume for each well was calculated using the following formula:

$$v = r^2 h (0.163)$$

Where:  $v$  = static volume of water in well, in gallons

$r$  = inside radius of well casing, in inches

$h$  = length of water column, in feet

0.163 = a constant conversion factor that compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.

To insure an influx of fresh water into the well, approximately two to four well volumes were extracted from each well before collecting the laboratory sample. All purge waters were contained by pumping the water directly into a tank truck, and transporting it to a single, 6,000 gallon storage tank at the City of Springfield's former sewage treatment plant, which is adjacent to the city-owned and operated Fulbright Pump Station (Figure 2.5-1). The tank is located within a secured area that is inaccessible to the public.

For those wells which did not already have operable pumps, purging was completed using either a Grundfos Model 16E13 Redi-Flo submersible pump (Teflon and stainless steel construction) or conventional bailers (PVC and Teflon types). Polyvinyl rope was used to maneuver the bailers. The Grundfos pump was secured by a stainless steel cable and a teflon-coated electrical cable. A flexible, PVC discharge hose was used

with the Grundfos pump. A portable gasoline-powered generator was used to operate the pump, so care was taken to situate the generator downwind of the well-head, and to keep all sample containers and equipment in a separate vehicle during mobilization. Table 2.5-1 presents ownership and physical data associated with each open well in the North U Drive area, as well as purging and sample identification information for those wells which were sampled.

It should be noted that the potentiometric information obtained during this sampling phase is of limited value for the following reasons:

- 1) Only one well (Thompson well) is known to be cased through the Northview Shale, the confining unit which separates the shallow and deep aquifers; and
- 2) Only three of the wells which were sampled are believed to be open solely within the shallow aquifer. The limited potentiometric data collected during the sampling of these wells shows that flow within the shallow aquifer, north of Parrish Drive, is to the north and east, towards the Little Sac River and Pea Ridge Creek, respectively. The remaining two wells sampled exhibited water levels which probably reflect a potentiometric balance between the two aquifers.

During the sampling activities, water levels were measured in two wells at the Holder residence at 4064 Northwood Drive. These wells are approximately 20 feet apart and, according to file information, are 441 feet deep and 191 feet deep. Water levels in these wells were determined to be 116 feet (BLS) and 114 feet (BLS), respectively. Because of the short distance between these wells, and their similar water levels, (the two-foot difference can be accounted for by topographic relief) it was decided to sample only the shallower of the two wells. However, when comparing the water-level measurement/well depth relationships of these two Holder wells with those for other wells in the study area (Table 2.5-1) it is evident that the deeper well has an anomalous water level. It is possible that the deeper well has been partially plugged, sealing the lower aquifer; otherwise, it should be assumed that some change in the hydrogeology is responsible for these aberrant circumstan-

TABLE A.5-1

WELL DATA SUMMARY  
(OPEN WELLS ONLY)  
NORTH U DRIVE SITE  
SPRINGFIELD, MISSOURI  
NOVEMBER 12-17, 1990

OWNER (PHONE #)	WELL LOCATION	TOTAL DEPTH (ft.)	AQUIFER	DEPTH TO WATER (ft.)	AQUIFER ELEVATION (MSL)	CASING DIAMETER (in.)	STATIC- WATER VOLUME	VOLUME PURGED (gal.)	PURGE METHOD	SAMPLE NUMBER (MG2019-G-#)
Loreta Degraffenreid (417)833-1816	2124 North Stagecoach	235	shallow	98 (BLS)	1,091 ft.	6	201	640	existing well pump	001
Francis Frakes (417)756-2324	4078 Old Highway 13	485	shallow/ deep	225 (BLS)	(t)	6	382	1,170	existing well pump	003
Richard Thompson (417)833-1874	Mobile Gardens Trailer Park	640	deep	286 (BLS)	945 ft.	6	520	1,560	existing well pump	004, 005
Hugh Wise (417)862-9926	Storage lot north of Frasier Bros. Co.	124 (apprx.)	shallow	94.5 (BLS)	1,117 ft.	6	43	150	Grundfos Submers- ible pump	006
Bob Holder (417)833-3021	4064 Northwood	191	shallow(*)	114 (BLS)	1,102 ft.	6	113	220	Teflon and PVC Bailers	007
Bob Holder (417)833-3021	2135 Parrish	423	shallow/ deep	256 (BLS)	(t)	6	245	400	Grundfos Submers- ible pump	008
Bob Holder (417)833-3021	4064 Northwood	441	unknown(*) (3)	116 (BLS)	1,102 ft.	6	477	NOT SAMPLED (1).....		
Ray Daugherty (417)833-1582	1929 North U Drive	400 (apprx.)	shallow/ deep	NA	NA	NA	NA	NOT SAMPLED (2).....		

BLS = Below Land Surface

(1) = Well was not sampled because it exhibited similar water level as the other well on the property, which was sampled.

(2) = Well was not sampled due to access restriction.

(\*) = Note similar (shallow) water levels for two Holder wells which are within 20 feet of each other but have widely disparate depths. Deep well may be partially plugged.

(t) = Water depths reflect potentiometric balance between two aquifers, not actual aquifer elevations.

NA = Information not available.

ces. Unfortunately, the well owner has not been available to provide additional information.

#### 2.5.2 Well Sampling

Before and throughout the purging process, samples from each well were tested for field parameters; specifically pH, specific conductivity and temperature. Stabilization of these parameters are necessary to ensure that a proper sample, representative of the aquifer waters, is collected. The results of this monitoring are presented in Table 2.5-2, along with other sample information.

Five of the six wells were sampled for laboratory analysis within 24 hours of purging. One well, at the Holder residence on Parrish Drive, was not sampled until approximately 48 hours after purging was initiated. This delay was the result of mechanical failures in the portable pump system. Where well pumps were already in place, samples were collected directly from the pump discharge pipe or the nearest outside tap. All other samples were collected with Teflon (for VOAs) or PVC (for other parameters) bailers. All residential well samples were analyzed for VOAs (including MTBE), BNAs, total metals, dissolved metals, pesticides and cyanide.

Aside from the six well samples, four additional samples were prepared to satisfy the quality assurance (QA) requirements for this sampling event. These quality control, or QC, samples were prepared to assess the sampling, decontamination and transport procedures as potential sources of contamination or cross-contamination, and to document overall sampling and analytical precision. Specifically, the set of QC samples consisted of:

- 1) One trip blank, prepared before arriving on site, intended to assess sample handling and shipment practices. This sample was analyzed for VOAs only, as the ubiquitous compounds within this fraction would be the most likely to contaminate samples or sampling equipment during handling and shipping;
- 2) One rinsate blank, included as a means of validating the equipment decontamination procedures. This sample was

**TABLE 2**  
**WELL SAMPLE SUMMARY**  
**NORTH U DRIVE SITE**  
**SPRINGFIELD, MISSOURI**  
**NOVEMBER 12-17, 1990**

SAMPLE #	SAMPLE LOCATION	WATER DEPTH (BLS) (SCREENED AQUIFER)	ANALYTICAL PARAMETERS	COLLECTION DATE/TIME	SPLIT	FIELD PARAMETERS											
						INITIAL			AFTER 1ST PURGE			AFTER 2ND PURGE			AFTER 3RD PURGE		
MG2019-G-#						pH	Ch (µmhos)	T(°C)	pH	Ch	T	pH	Ch	T	pH	Ch	T
001	Degraff-enreid Well	98 ft. (shallow)	Entire TCL, plus MTBE	11-12-90/ 1415 hrs.	None	6.4	(*)	15	6.15	(*)	15	(-)	(-)	(-)	6.0	900	15
003	Frake Well	225 ft. (shallow/deep)	Entire TCL, plus MTBE	11-12-90/ 1830 hrs.	None	6.9	550	17	6.9	570	14	6.9	600	14	6.9	605	14
004	Thompson Well	286 ft. (deep)	Entire TCL, plus MTBE	11-13-90/ 1030 hrs.	MDWR & Steve Sturgess	7.5	850	16	7.2	945	16	7.2	915	16	7.2	900	16
006	Wise Well	94 ft. (shallow)	Entire TCL, plus MTBE	11-14-90/ 1100 hrs.	Frazier Bros. Constr. Co. & Jack Frazier	6.5	820	14	6.5	810	14	7.0	770	15	7.0	740	16
007	Holder Jr. Well (Northwood Drive)	114 ft. (shallow)	Entire TCL, plus MTBE	11-17-90/ 1330 hrs.	None	7.0	280(a)	14	6.8	790	14	6.6	800	14	(-)	(-)	(-)
008	Holder Sr. Well (Parrish Drive)	256 ft. (shallow/deep)	Entire TCL, plus MTBE	11-17-90/ 1600 hrs.	None	7.0	620	16	6.7	650	14	6.8	670	14	(-)	(-)	(-)
002	Trip Blank	NA	VOAs, plus MTBE	11-12-90/ 1000 hrs.	NA.....												
005	Thompson Well	Duplicate of sample MG2019-G-004, listed above.....															
009	Rinsate Sample	NA	Entire TCL, plus MTBE	11-17-90/ 1645 hrs.	NA.....												
010	Quality Control Check Sample	NA	VOA, BNA, Total Metals, Cyanide, and Pesticide Fractions	NA.....													
011	Purge Water Holding Tank	NA	VOAs, BNAs and Total Metals	12-10-90/ 1100 hrs.	NA.....												

BLS = Below Land Surface.

(\*) = No reading due to equipment malfunction.

(-) = No measurement recorded.

(a) = Anomalous measurement.

NA = Not applicable.

analyzed for the full scope of priority pollutant parameters, as were each of the well samples;

- 3) One field duplicate, intended to assess the consistency of the overall sampling and analytical system. This sample was also analyzed for all priority pollutant compounds; and
- 4) One spike, or quality control check sample, prepared by the MDNR laboratory for the purpose of evaluating the analytical techniques of the contract laboratory (in this case E & E's ASC). The MDNR Laboratory Services prepared a spike for each of the parameters included in the well sample analyses, with the exception of dissolved metals.

A sample was also collected from the purge-water holding tank, to determine whether any special handling will be required to dispose of this water (about 4,000 gallons). This sample was analyzed only for analyzed for the full scope of priority pollutant parameters, as were each of the well samples;

those parameters most likely to be identified in the individual well samples, namely VOAs, BNAs, and total metals.

Contract Laboratory Program (CLP) analytical procedures were used for all samples collected during this phase of the investigation and a full CLP package, included as Appendix C-2 with this report, was provided with the results.

Split samples were provided to the MDNR and property owners upon request. The MDNR requested a split sample of the Thompson well located at the Mobile Gardens Trailer Park. One property owner, Jack Frazier, requested a split sample from the Wise well located at the equipment storage lot leased by Mr. Frazier.

### 2.5.3 Sample Packaging And Preservatives

All samples collected during the Phase 1 investigation were considered low concentration environmental samples, and were packaged and handled according to U.S. EPA Region VII SOP 2230 and 2334 for Sample Collection, and SOP 2130 for Sample Documentation and Management.

Packaging requirements vary according to the media sampled and the analysis to be performed on the sample. Table 2.5-3 summarizes the

TABLE 2.5.3

## SAMPLE PACKAGING SUMMARY FOR COMMON ANALYTICAL PARAMETERS

ANALYSIS	CONTAINER (Approximate Volumes Required)		PRESERVATIVE FOR WATER *	MAXIMUM HOLDING TIMES
	WATER	SOIL		
Metals Total or Filtered	1 liter cubitainer (at least 1/2 full)	1 8 oz. jar, Teflon lined cap (2/3 full)	HNO <sub>3</sub> to pH <2; cool to 4° C	6 months
Semi-Volatiles (Base-neutrals, acids)	2 liter amber glass jar, Teflon lined cap (Full with some head space)	1 8 oz. jar, Teflon lined cap (2/3 full)	Cool to 4° C	7 days for extraction; 40 days for analyses
Pesticides	2 liter amber glass jar, Teflon lined cap (Full with some head space)	1 8 oz. jar, Teflon lined cap (2/3 full)	Cool to 4° C, pH 5-9	7 days for extraction; 40 days for analyses
Volatiles	2 - 40 ml glass vials, Teflon lined cap (Full, <u>NO</u> head space)	2 - 40 ml glass vials, Teflon lined cap (as full as pos- sible)	Cool to 4° C; isolate vials in cubitainer	14 days
Cyanide	1 liter cubitainer (at least 1/2 full)	1 8 oz. jar, Teflon lined cap (2/3 full)	NaOH to pH >12; cool to 4° C	14 days

\* Preservatives for all soil samples is cool to 4°C

packaging and preservation requirements, and holding times for all sample media and analysis.

Labels identifying the sample number, collection date and time, analytical parameter(s) and appropriate preservative(s) were placed on each sample container. Prior to shipping, containers were placed into plastic-lined coolers, along with foam packing material. The plastic liner was then sealed and ice was placed between the liner and the walls of the cooler to help preserve the samples. Each cooler was accompanied by a chain-of-custody form, and sealed with signed and dated custody tape.

#### 2.5.4 Equipment Decontamination

All non-dedicated sampling equipment was decontaminated between wells. The decontamination procedure consisted of an Alconox/deionized water wash, followed by a clean water rinse. Due to the large amount of water required to clean the Grundfos submersible pump and its accessory cables and discharge hose, municipal water was used during the rinse stage. This water was obtained from a spigot located at the former sewage treatment plant, where the decontamination line was staged, and therefore transportation of the water was not required. The submersible pump and discharge hose were decontaminated by placing the pump in a 30-gallon container of rinse water and pumping water through the system. Water was continuously fed into the container until at least 200 gallons had passed through the system. The exteriors of the pump cables and hoses were scrubbed in the Alconox/deionized water wash and rinsed with municipal water.

All residues and fluids generated by the decontamination procedures were contained in the purge water holding tank, located at the decontamination station. Dedicated, or disposable investigation-derived wastes, such as bailer rope and surgical gloves, were containerized in large plastic bags. These bags were sealed and stored inconspicuously inside of an abandoned building at the decontamination area. The decontamination area was located at the city-owned former sewage treatment

plant (Figure 2.5-1). This former plant is surrounded by a 6-foot, barbed-wire fence and is accessible only through a locked gate.

## 2.6 DEVIATIONS FROM THE GUIDANCE DOCUMENTS

Prior to conducting the Phase 1 field activities, four guidance documents were prepared to present the procedures necessary to successfully implement the activities and fulfill the objectives associated with each activity. Specifically, these documents are:

- 1) Site Safety and Health Plan, designed to provide all information necessary to assess the health and safety risks associated with performing the field activities;
- 2) Quality Assurance Project Plan (QAPP), providing the policies, organization, objectives, functional activities, and specific quality assurance (QA) and quality control (QC) activities that typically will be implemented by E & E for a given project. The QAPP is designed to ensure that all technical data generated by E & E's Analytical Services Center (ASC) are accurate, representative, and will ultimately withstand judicial scrutiny;
- 3) Work Plan, providing overall guidance for the performance of the RI, and Phase 1 in particular; and
- 4) Field Sampling Plan (FSP), prepared to supplement the Work Plan with specific details relating to background information, sampling objectives, sampling methods and equipment, and sample handling procedures.

During the course of Phase 1 field activities some procedures, deviating from those described in the guidance documents, were implemented to accommodate site-specific conditions or concerns. These modifications, summarized in the following paragraphs, were based on sound, professional judgment, and were in no way detrimental to the quality of the field data.

- o Decontamination Procedures: Equipment decontamination was performed using the procedures outlined in the Field Sampling Plan (FSP) for this site; that is, an Alconox/water wash followed by a deionized water rinse. During the groundwater sampling activities, municipal water was sub-

stituted for deionized water during the rinse stage due to the large quantities of water needed to clean the pump and discharge pipe. The QAPP (pp 5-9) indicates a more rigorous sequence of decontamination procedures. This protocol is actually a "boilerplate", intended to serve as a guidance for the most stringent decontamination requirements. The decontamination procedures used in the field were quite adequate for the low-level contamination associated with this site and were in accordance with the Work Plan and FSP with the exception of the use of city water. Rinsate blanks were collected during both the groundwater and soil sampling phases to ensure these procedures were properly exercised and effective.

- o Quality Assurance (QA) samples associated with the groundwater sampling activities were prepared according to the Work Plan and FSP, except that the spike was prepared by the MDNR rather than the EPA. The QAPP indicated that a field blank would be collected. This conflicted with the Work Plan and FSP. Table 2-1 in the QAPP indicates that one "field blank" (a term used collectively in this table to include all types of blanks) and one duplicate would be collected as a measure of QA for the sample collection, equipment decontamination and sample shipment procedures. This reference to a "field blank" was in error. The reference should simply be to a blank sample and not a field blank. Table 5-1, also in the QAPP, was inserted to show the typical frequency of different types of QC samples which may or may not be taken for a specific matrix at a given site. This table was not intended to summarize all of the QA sample types that would be prepared specifically for the Phase 1 groundwater sampling event. In fact, a duplicate sample (checking sample collection and analysis procedures), a trip blank (regulating sampling handling and shipment practices), a rinsate blank (validating equipment decontamination procedures) and a spike sample (laboratory performance evaluation) were prepared for this sampling event. A field blank, generally prepared as a means of assessing ambient field conditions, was not prepared at this site. Considering the setting of the study area, the small number of samples collected, and the comprehensive QA imposed on the sample collection, sample handling, and decontamination procedures, this additional blank was thought to be unnecessary. Typically, QC samples comprise 10 to 20 percent of the entire sample lot for a given event. For this sampling event, nearly 40 percent of the samples were prepared for QC purposes.
- o Regarding the soil-gas sampling activities, the QAPP, FSP and Work Plan state that duplicate soil-gas samples were to be collected as part of the QA procedures. However, be-

cause an air sample cannot feasibly be homogenized and separated into different containers under field conditions, soil-gas "duplicates" (actually laboratory duplicates) were prepared from a single field sample. This sort of QC sample is useful in estimating the analytical precision of any given laboratory procedures. Equipment and ambient air blanks were also prepared to ensure the validity of the sampling procedures.

- o According to the QAPP, at least three static water volumes were to be purged from each well prior to sampling. This requirement was fulfilled at four of the six well locations. However, at the last two sampling locations, the Holder Sr. and Holder Jr. residences, only two volumes were purged. Due to the drop in the potentiometric surface of the deep aquifer (the level has dropped between 100 and 125 feet since 1985), purging was particularly difficult at the Holder Sr. well, where it was eventually necessary to lower the submersible pump approximately 350 feet below the surface to sustain even a semi-continuous purge flow. Because of the increased time requirements needed to accomplish this, it was decided that the Holder Jr. well, developed in the shallow aquifer, would be bailed by hand contemporaneously with activities at the Holder Sr. well.

After purging approximately 400 gallons from the Holder Sr. well, recharge of the well appeared to stop completely and it became obvious that either the pump or hose had been damaged. By this time, the field parameters (pH, conductivity and temperature) had stabilized and it was decided to pull the pump and sample the well, rather than repair and re-install the pump. Upon pulling the pump, it was discovered that the discharge hose had ruptured near the pump connection suggesting that it had probably been subject to a pressure threshold. At the same time it was decided that only two static water volumes would be bailed from the Holder Jr. well, providing that the field parameters had stabilized by that time. This would eliminate the need for decontaminating the pump and accessories between wells and also greatly reduce the on-site time charged by the water truck operator. Field parameters had, in fact, stabilized after purging two well volumes and the well was sampled.

- o The pH meter became inoperable on the fourth day of field work (Thursday, November 15). It was decided that measurements could be continued through the use of pH paper. This method is accurate to within approximately .25 to .5 pH units.

### 3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA

#### 3.1 CLIMATOLOGY

The climate of the North U Drive area may be considered as a "Plateau Climate" with moderate temperatures. Winters are cold usually from December through February. Summers are hot, and spring and fall are relatively short. The annual mean temperature at the Springfield airport is 55.9 degrees Fahrenheit (°F). The mean annual maximum and minimum are 67.4°F and 44.3°F, respectively (NOAA 1982). Average monthly maximum, minimum and mean temperatures are shown in Table 3.1-1.

Precipitation follows a somewhat biannual pattern with drier winters and summers, and relatively wet transitional seasons. The average annual precipitation for Springfield is 39.47 inches (NOAA, 1982). However, in 1990 the Springfield area experienced a record rainfall of 63 inches. Table 3.1-2 shows the average annual rainfall distribution.

#### 3.2 SURFACE WATER HYDROLOGY

A surface water reservoir for the Springfield community water supply is located along the eastern portion of the study area, approximately 1,200 feet east of the nearest contaminated well. However, the nearest upgradient source of potentially contaminated surface runoff is the Montgomery Metal Craft tank yard, located approximately 1/4 mile west of the reservoir. Figure 3.2-1 shows the drainage patterns in the study area. Runoff from this facility would move south and southeast of the property, and then potentially back to the northeast, toward the reservoir (USGS 1961). The migration pathway would therefore be greater than 1/4 mile (actual distance of about 1/2 mile), but this does not lessen the relevant concerns. Water from the reservoir eventually enters the

**TABLE 3.1-1**

**SPRINGFIELD MUNICIPAL AIRPORT  
TEMPERATURE NORMALS (1951 - 1980)  
(°F)**

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
MAXIMUM	42.2	47.1	56.1	68.3	76.5	84.9	89.8	89.3	81.6	70.8	56.2	46.4	67.4
MINIMUM	20.8	25.3	33.0	44.0	53.1	61.9	66.2	64.7	57.3	45.5	33.9	25.9	44.3
MEAN	31.5	36.2	44.6	56.2	64.8	73.4	78.0	77.0	69.5	58.2	45.1	36.2	55.9

Source: NOAA, 1982

**TABLE 3.1-2**

**SPRINGFIELD MUNICIPAL AIRPORT  
AVERAGE PRECIPITATION (1951 - 1980)**

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
1.60	2.13	3.44	4.03	4.37	4.66	3.58	2.83	4.24	3.20	2.89	2.55	39.47

Source: NOAA, 1982

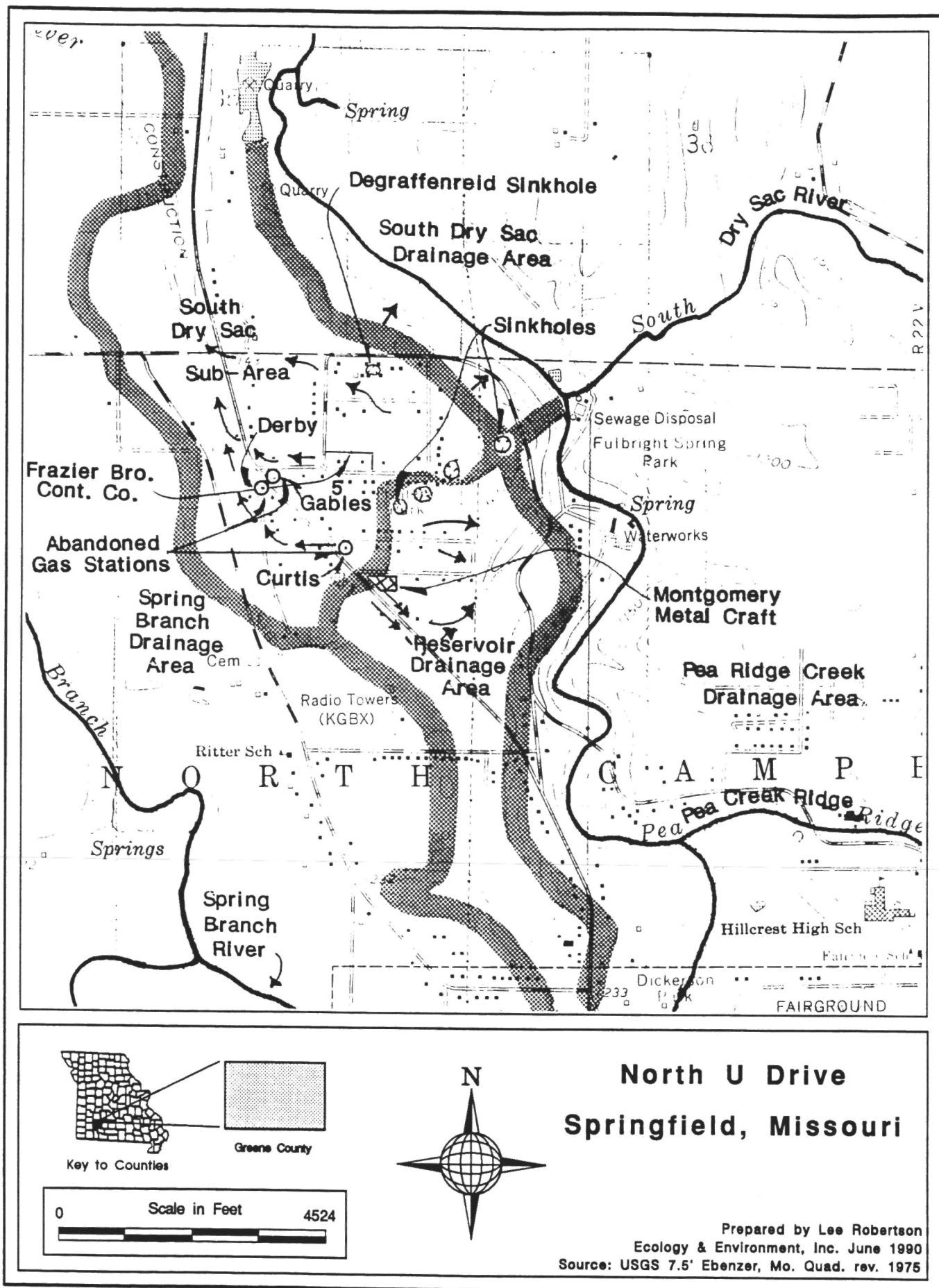


Figure 3.2-1: SURFACE WATER RUNOFF PATTERNS

Springfield municipal distribution system which serves the entire population of Springfield. The only other potential sources of contaminated surface runoff would be the Frazier Brothers Construction Company and the former Curtis service station. Local topography suggests that runoff from the construction company moves north, away from the reservoir, and runoff from the empty lot (former Curtis Service Station) migrates south and southwest, crossing Old Highway 13, and avoids the drainage feature leading toward the reservoir from the southwest. (USGS 1961; Green County 1981).

Other potential surface water targets are: Spring Branch which flows southwest of the North U Drive area, west of Highway 13; the Little Sac River, situated northeast of the North U Drive area; and Pea Ridge Creek, which flows east of North U Drive.

Spring Branch could potentially receive runoff from both the former Curtis Service Station lot and the portion of Montgomery Metal Craft located west of Old Highway 13. The probable point of entry (PPE) to this perennial stream is about 3/4 mile southwest of the latter facility. Spring Branch drains into the Little Sac River at a location approximately 1 3/4 miles north of the PPE (USGS 1961).

The Little Sac could also receive runoff from the Frazier Brothers Construction Company, via an intermittent drainage route. The PPE to this drainage feature is approximately 1/2 mile northwest of Frazier Brothers Construction. In turn, the intermittent drainage path empties into the Little Sac River about 4/5 mile north of the PPE. This confluence is closer to the North U Drive area than the Spring Branch confluence, though it is still at least 1 1/2 miles downstream of the Springfield Waterworks at the Fulbright Spring location (USGS 1961).

Pea Ridge Creek could also receive contaminated runoff from the North U Drive area. A drainage route between Pea Ridge creek and the Montgomery Metal Craft tank yard on the east side of Old Highway 13 is interrupted by the municipal reservoir mentioned previously (USGS 1961).

Each of these three perennial water bodies (Pea Ridge Creek, Spring Branch, and Little Sac River) are used for recreational purposes. Consequently, their contamination could result in dermal contact or inges-

tion exposures, either through swimming and boating, or through the consumption of contaminated fish.

### 3.3 GEOLOGY/HYDROGEOLOGY

#### 3.3.1 Regional Geology/Hydrogeology

The Springfield area is underlain by rock units belonging to the Osagean and Kinderhookian Series of the Mississippian System, the Canadian Series of the Ordovician System, and the Upper Series of the Cambrian System. Beneath these sedimentary formations, approximately 2,000 feet beneath the surface, lies the Precambrian basement, composed of igneous and metamorphic rocks (Thomson 1986).

Near Springfield, the Osagean series consists of the following formations, in descending order: Burlington-Keokuk, Elsey, and Pierson.

The Burlington-Keokuk Limestones represent approximately 150 feet of light-gray, coarsely-crystalline, crinoidal limestone. Chert zones occur about 15 to 20 feet apart, with relatively pure calcium carbonate in between. The Elsey formation is a finely crystalline, gray, fossiliferous limestone interbedded with nodular chert. The Elsey averages 50 to 60 feet in thickness in Greene County. The Pierson Formation consists of dolomitic cherty limestone in the upper part, grading to a silty dolomite near its lower boundary. To the north of Springfield this formation thins as it becomes less dolomitic. In Greene County, the Pierson averages about 40 feet in thickness (MDNR 1978).

With respect to hydrogeology, the rocks of the Osagean Series constitute what is known as the Springfield Plateau aquifer (a.k.a. the "shallow", "upper", or "minor" aquifer in the Springfield area). This aquifer is characterized by Karst zones throughout, though Karst activity is particularly common within the Burlington-Keokuk Formation. This formation, and its associated residuum soil, contains caves, pinnacles and solution-enlarged joints. Sinkholes have formed where roofs of underground openings have collapsed. These sinkholes, along with subsurface voids that are not visible at the surface, are present over the entire area. Clusters of sinks and caves are an indication of intense Karst activity, and several of these features are located in the North U Drive area.

Yields within the Springfield Plateau aquifer are usually less than 20 gallons per minute (gpm) and the water quality is generally adequate only for domestic and stock use. The contamination potential for this aquifer is obviously high due to the extensive network of solution enlarged joints and fractures in the karst terrain (USGS 1989).

Prior to groundwater development in this area, water levels in the Springfield Plateau aquifer reflected the influence of local topography. Beneath recharge areas of higher elevation, such as the North U Drive area, the water table may be 100 feet or more below the land surface. However, migration within this aquifer below the site is difficult to predict for two principal reasons:

- 1) The area of interest covers a topographic divide; and
- 2) The karst terrain features may actually control localized flow in some areas.

During the Phase 1 groundwater sampling, depths to water varied between 95 and 114 feet below ground surface (BGS) at the different wells thought to be open to the shallow aquifer only. The limited potentiometric data obtained from these measurements indicates that flow within this aquifer is to the north and east, towards the Little Sack River and Pea Ridge Creek, respectively.

Beneath the Springfield Plateau aquifer are rocks of the Kinderhookian Series (also Mississippian aged) which collectively form the Ozark confining unit. In Greene County the specific formations within this series are, in descending order: the Northview Formation, the Compton Formation, and the Bachelor Formation (MDNR 1986).

The Northview Formation is extremely variable in Greene County, ranging from 5 feet in thickness in the southern part of the county, to 80 feet in the northern part (MDNR 1978). Beneath the site, the Northview exhibits a rather uniform thickness of about 40 feet, as determined by downhole geophysical data collected by DGLS in 1985 from several wells in the North U Drive area. Where the Northview is thickest, the lower part is primarily a dolomitic siltstone and shale, and the upper part is a silty dolomite. Several prominent siltstone beds are present

in the upper half of the Northview where it is more vertically extensive. In the southern part of the county, however, where the Northview is thinnest, the lithology is dominated by silty shale which is usually greenish-gray in color (MDNR 1978).

The Compton Formation is usually a light-gray limestone containing small crinoid ossicles in a finely crystalline matrix. In northern Greene County, this formation has been partially dolomitized to a brown to tan, earthy dolomite. The Compton averages 10 to 15 feet in thickness and has a sharp basal contact with the underlying Bachelor Formation (MDNR 1978).

The Bachelor Formation marks the base of the Mississippian System and consists of two lithologies, a basal green quartzose sandstone and an upper greenish shale. Both units of the Bachelor Formation are laterally extensive, though each averages a thickness of only 3 to 4 inches (MDNR 1978).

Of the several geologic formations in the Ozark confining unit, the Northview is the most effective in impeding the flow of water between the upper and lower aquifers. The estimated hydraulic conductivity of this confining unit ranges from  $1 \times 10^{-8}$  to  $5 \times 10^{-8}$  ft/s (USGS 1989). However, this confining unit is breached extensively by fractures and larger joints, faults, and most recently, by uncased water wells. In fact, two normal faults, the Ritter fault and the Fulbright fault, occur within 1/4 mile of the contaminated wells associated with this site (Thomson 1986).

These faults are both part of the King-Ritter Fault Zone. The northernmost (Ritter) fault associated with this complex extends west from Fulbright Springs to just south of Willard. The south side of this fault has been upthrown between 80 and 130 feet, closer to 80 feet near the site (Thomson 1986).

The central (Fulbright) fault, the trace of which is just south of the site, extends west across Highway 13 and east, approximately to Highway H. The northern, downthrown block of this fault has undergone widely variable displacement in terms of sheer magnitude. However, recent studies have determined this displacement to be about 60 feet

within one mile west of the site (Middendorf 1990), and about 20 feet immediately south of the site (MDNR 1985).

Another fault associated with the King-Ritter Fault Zone is the King fault. It is the southernmost of the three faults and the most difficult to detect. Although its vertical throw is in excess of 50 feet, it is nearly one mile from the nearest polluted well and is not likely to affect contaminant migration originating in the North U Drive area.

The actual "rate of leakage" throughout the Ozark confining unit is further controlled by the vertical hydraulic gradient of the unit and the lateral hydraulic gradient across the unit. A hypothetical vertical volumetric leakage rate of  $[5.2 \times 10^{10} K_v] \text{ft}^3/\text{s}$ , where  $K_v$  is the vertical hydraulic conductivity (in ft/s) of the Ozark confining unit, has been calculated for aquifer conditions beneath the confining unit prior to development. A similar calculation under 1987 drawdown conditions yielded a leakage rate of  $[11.6 \times 10^{10} K_v] \text{ft}^3/\text{s}$ , a 100 percent increase over the predevelopment leakage rate (USGS 1989).

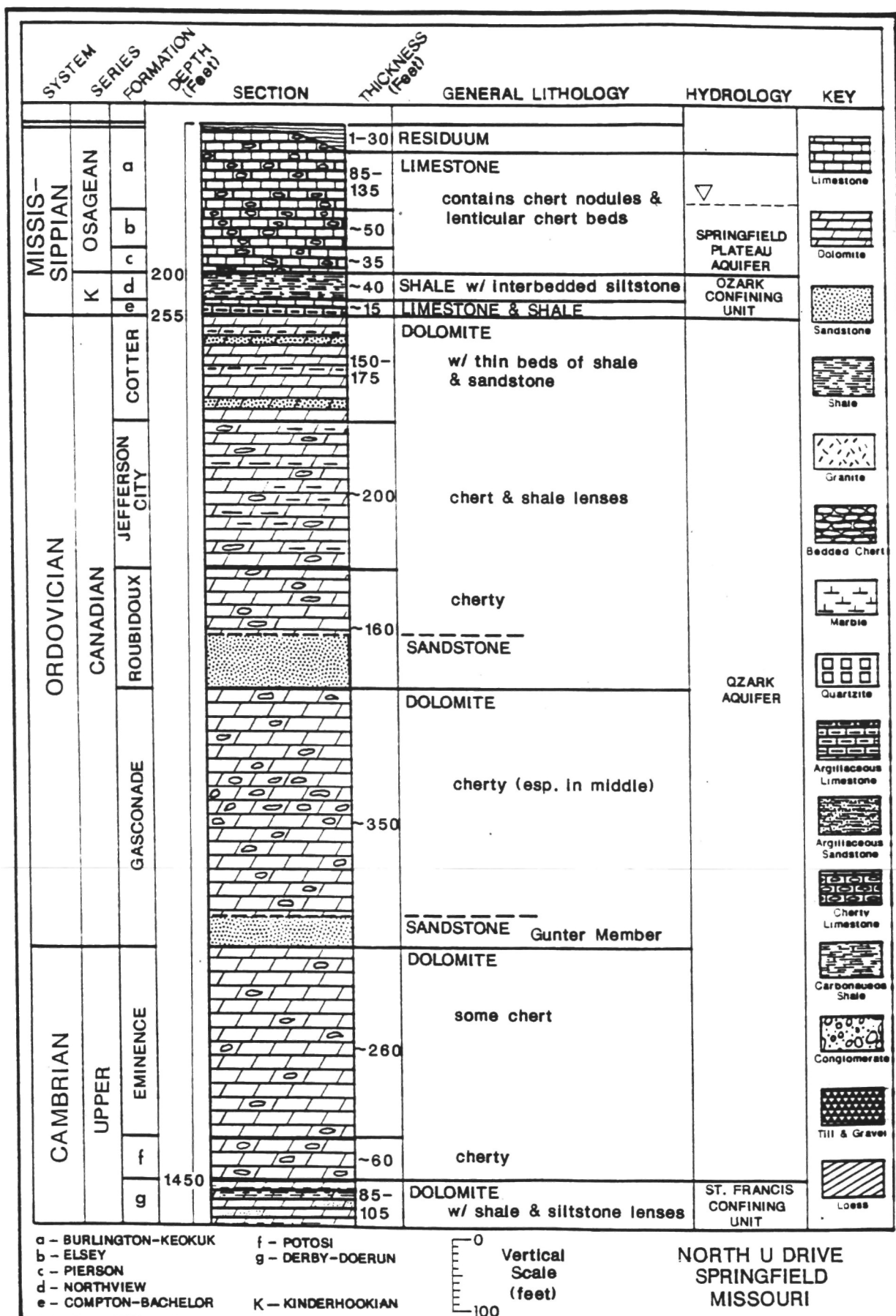
Beneath the Ozark confining unit are formations of the Canadian Series of Ordovician age. In descending order, these units are: the Cotter Dolomite, a light gray to light brown, medium to finely crystalline dolomite which weathers to rounded, black-stained surfaces and is 50 to 175 feet thick in Greene County. Chert and thin beds of green shale and sandstone can be found throughout this formation; the Jefferson City Dolomite, a light brown to brown, medium to finely crystalline and argillaceous dolomite. This formation is 190 to 220 feet thick, and is divided from the similar, overlying Cotter dolomite by a massive chert breccia unit which occurs near the top of the unit; the Roubidoux Formation, predominantly a light gray to brown, finely crystalline cherty dolomite. In Greene County, a small part of this unit is a fine to medium-grained quartz sandstone which has characteristically sub-rounded and frosted grains. The Roubidoux is 140 to 180 feet thick throughout the county; and, the Gasconade Dolomite, a light brownish-gray, cherty dolomite, with a thickness between 250 and 450 feet in the Springfield area (MDBA 1961; Thomson 1986).

Underlying these formations are rocks in the Upper Series of the Cambrian System. The two youngest formations of this series, the Eminence Dolomite (250 to 350 feet thick) and the Potosi Dolomite (20 to 120 feet thick) combine with the Ordovician formations to form the Ozark aquifer (Thomson 1986). Figure 3.3-1 is a generalized stratigraphic section for all strata between the surface and the bottom of the Ozark aquifer.

Near Springfield, the highest yielding formations within this aquifer are the Roubidoux Formation, the lower Gasconade Dolomite and the Potosi Dolomite. Water wells open to the entire thickness of this aquifer (up to 1,450 feet thick near Springfield) generally yield more than 1,000 gallons per minute, a sufficient rate for municipal and industrial needs (USGS 1989).

The lateral hydraulic conductivity of the Ozark aquifer ranges between  $8.0 \times 10^{-5}$  and about  $1.3 \times 10^{-4}$  ft/s. The corresponding aquifer transmissivity is between approximately  $1.0 \times 10^{-1}$  ft<sup>2</sup>/s and  $1.7 \times 10^{-1}$  ft<sup>2</sup>/s (USGS 1989). Prior to development, flow within this aquifer was dominated by a west-to-northwesterly component in the area which now contains North U Drive. In response to groundwater withdrawals, however, a large cone of depression has formed within this aquifer in the vicinity of Springfield, and flow beneath North U Drive has been altered from its natural course. File information, obtained prior to Phase 1 field activities, indicates that flow within the deep aquifer is currently dominated by a south-to-southwesterly component (USGS 1989). The maximum drawdown within this aquifer, as of August 1987, was estimated to be 300 feet in an area near the western edge of Springfield's city limits (USGS 1989).

However, during the Phase 1 groundwater sampling, it was determined that the depth of the lower aquifer beneath the study area has dropped over 100 feet since measurements were last made in 1985. The water level in the state-approved Thompson well (cased all the way through the Northview shale) was measured at an elevation of +945 MSL, approximately 150 feet below 1985 levels measured at this well and other wells nearby that were open exclusively to the lower aquifer. Wells open to both



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JULY 1990

SOURCE: Thomson, K.C., Geology of Greene County, Missouri, 1986  
USGS Water Resources Investigations Report 89-4079, 1989

Figure 3.3-1: Generalized Stratigraphic Column

aquifers have also exhibited water level drops, closer to 100 feet, that are less severe, probably due to interflow with the shallow aquifer.

According to a local well service contractor, water levels north of Springfield dropped significantly during the summer and fall of 1989. A drought during this interval culminated what had been a relatively dry decade, and deep well facilities were operating for extended periods (Parker 1991). The contractor believed extensive pumping into Lake McDaniel, Springfield's primary water reservoir, was responsible for the aquifer depletion. Lake McDaniel is located approximately 1.5 miles northeast of the study area.

The City of Springfield maintains five wells at Lake McDaniel, operating them only to sustain a minimum water level in the reservoir. The wells have 16-inch casings and are 1,335 feet to 1,403 feet in depth. Their pumping capacities range between 437 gallons per minute (gpm) and 1,137 gpm (Parker 1991). According to Mr. John Parker, superintendent at the Fulbright Pump Station, these wells were indeed used during the dry spell in 1989. However, Mr. Parker indicated that no significant drops in the aquifer elevation were recorded at the lake during the replenishment period. (Only one well at a time is pumped, while water levels are monitored in the others.)

Much closer to the study area, at the Fulbright Pump Station, the city operates a 1,600-foot water supply well. This well, which can produce up to three million gallons per day (gpd), is operated periodically (seven or eight months at a time) to maintain an adequate pool level in the water reservoir at the pump station. The most recent pumping interval was from June 1990 through January 1991. Typically, the well shuts down for four to five months between periods of operation (Parker 1991). This well was operating several months prior to the Phase 1 groundwater sampling in November 1990). The relatively low water levels recorded at this time very likely reflect the combined effects of the concurrent pumping at Fulbright, the extended pumping at Lake McDaniel during the summer/fall of 1989, the drought conditions experienced over the entire area during the past few years, and the steady growth in demand (about 10% per year) that has occurred since 1985.

It should be noted that the Springfield area received 63 inches of rainfall in 1990, a record-high amount, and it would therefore be expected that more recharge would have occurred since 1989 (Witherspoon 1991). One explanation for the seemingly slow recharge in the study area may be that the grouting of over 60 wells in the area has significantly reduced local interconnection between the aquifers. Many of the plugged wells were open to both aquifers, thus the lower aquifer was provided an additional means of recharge (from the upper aquifer) at these point sources. This additional recharge had likely caused a potentiometric "mound" within the deep aquifer beneath the study area. The increased pumping of the lower aquifer, and the elimination of several recharge point sources for this reservoir, has had a combined influence in maintaining a deeper potentiometric surface beneath North U Drive.

There is a potential point of interest regarding the connectivity between aquifers within the study area. There are two open wells located at the Holder Jr. residence, 4064 Northwood Drive, that have supposedly been finished at depths of 446 feet and 192 feet. File information indicates that the deeper well is cased slightly above the Northview Shale and, therefore, receives contribution from both aquifers. The shallower well is finished entirely above this confining unit, and is open to the shallow aquifer only. During the Phase 1 groundwater sampling, at which time the shallower well was sampled, water elevations in each well were identical.

The water elevation in each well fit the expected pattern for the potentiometric gradient of the shallow aquifer. However, the water elevation in the deeper well, open to both aquifers, was 135 feet higher than the water elevation in the nearest deep well. This latter well, located at the Holder Sr. residence on Parrish Drive, was also open to both aquifers and, coincidentally, set at the same surface elevation. At the time of sampling, this contrast in water levels was attributed to the probability that the deeper well at the Holder Jr. residence on Northwood Drive had been partially plugged, only up to or through the Northview shale. In this case the deeper well would have essentially

been transformed to a "shallow" well, and expected to exhibit water levels consistent with those associated with the shallow aquifer. The well owner was not available to confirm this theory.

However, identical water levels in the two Holder wells on Northwood Drive were also recorded during geophysical logging activities performed by the MDNR in 1985. At that time, the deeper well was known to be completely open. The potential remains, therefore, that an anomaly in the hydrogeologic conditions exists between the two Holder residences. One possibility is that a fault, acting as a low permeability groundwater barrier, has created a large difference in potentiometric surface elevations. Faults that possess a thin (but continuous) layer of gouge may form almost impermeable barriers. Figure 3.3-2 schematically illustrates the effect of this fault configuration on the water table position. It is expected that groundwater flow would be approximately perpendicular to the strike of the fault, creating a "groundwater cascade" in the fault zone.

### 3.3.2 Study Area Investigation

Although a substantial amount of regional geologic information is available for the general Springfield area, it was anticipated that more localized geologic information could be obtained within the study area through the application of surface geophysical techniques. The geophysical survey designed for the subsurface geologic investigation had two primary exploration targets:

- 1) to determine the depth and spatial configuration of the bedrock, and
- 2) to identify significant fracture trends or large, singular conduits beneath the surface.

A combination of seismic refraction, electrical resistivity, and VLF data was collected for these purposes.

As mentioned in Section 2.4.1 the refraction data did not always allow for quantitative analysis due to the erratic bedrock surface. However, several seismic records collected during the study did provide

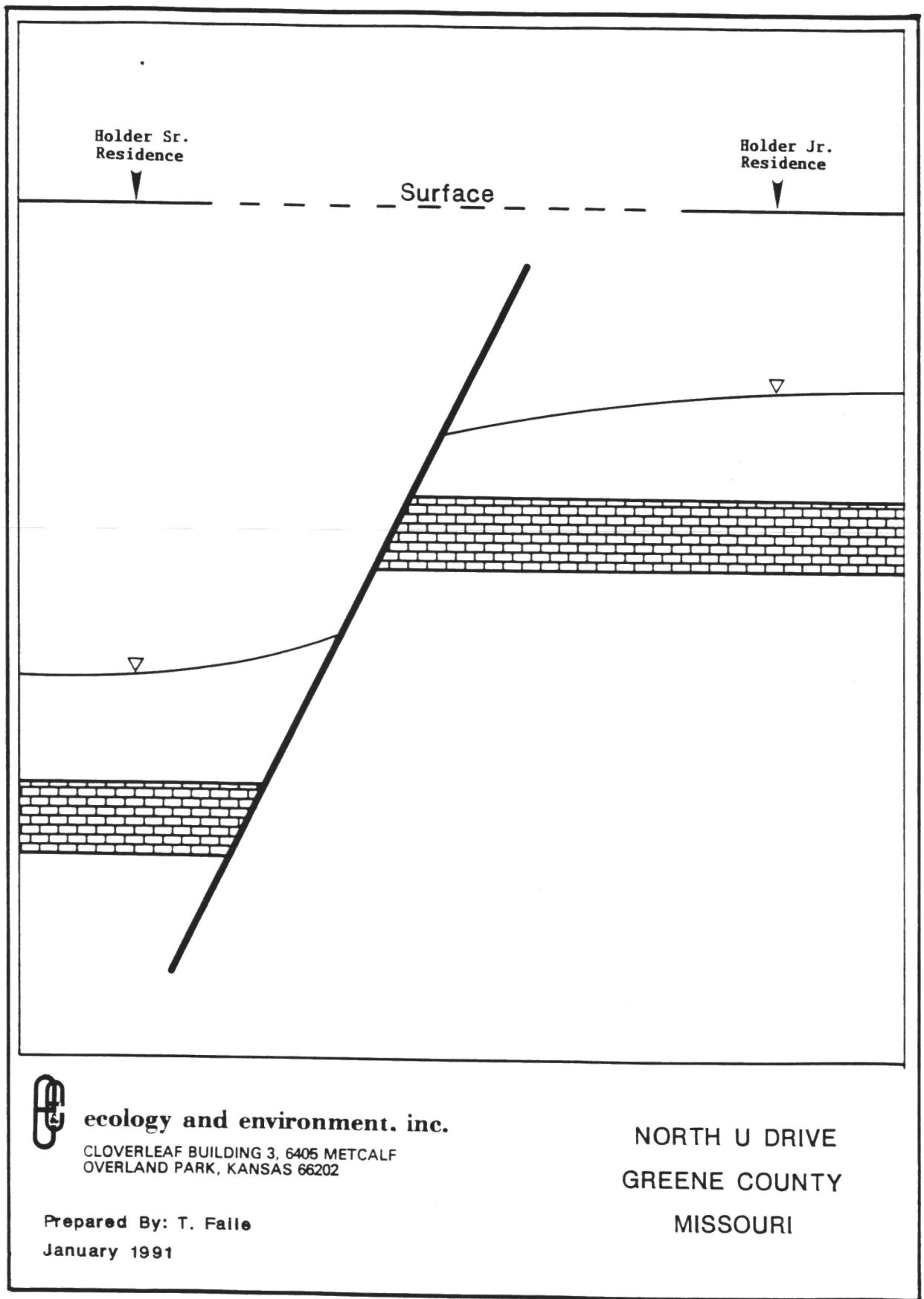


Figure 3.3-2: Schematic Diagram of a Fault  
as a Low Permeability Groundwater Barrier

reducible data with which layer velocities and depths could be estimated. In some cases, even the non-reducible data was beneficial as it was indicative of particularly karstic areas. Appendix B-1 contains the depth calculation sheets for reducible lines, shot records, and time-distance graphs for all seismic lines.

Calculated velocities fall into four distinct groups. These groups are given layer designations 1 through 4 as shown in Table 3.3-1. Layer 1 represents a thin veneer of loosely consolidated soil. The second layer is a continuation of the soil profile whose velocity can increase due to greater compaction of the soil or larger, more numerous rock fragments. Layer 3 represents the weathered bedrock with velocity increasing as the amount of weathering decreases. The deepest refractor, layer 4, yields velocities representative of competent limestone bedrock.

Calculated depths from the seismic data were subtracted from shot-point elevations and plotted on a study area map (Figure 3.3-3), along with top of bedrock elevations at various well locations. The well data was derived from geophysical logs which were collected by the MDNR/DGLS prior to the well-closing activities in 1985.

Numerous contour maps, as described in Section 2.4.2, were generated from the resistivity survey data. These maps were then evaluated for information pertaining to the subsurface geology. In general, all the maps revealed the karstic nature of the study area. The resistivity contour map, connecting subsurface elevations where the first 500 ohm-ft apparent resistivities occur (Figure 3.3-4), is very consistent with bedrock elevations from the well and seismic data. This map was incorporated with the well and seismic data to generate a single bedrock topography contour map (Figure 3.3-5).

The resistivity data, plotted and contoured as a pseudo cross-section, show apparent resistivity reversals with respect to depth. Where resistivity values decrease with depth, a potential weathered fracture zone or conduit, filled with material more conductive than bedrock, is indicated. Conversely, if a conduit or fracture is open, the high electrical resistance of air is encountered, and the apparent

**TABLE 3.3-1**

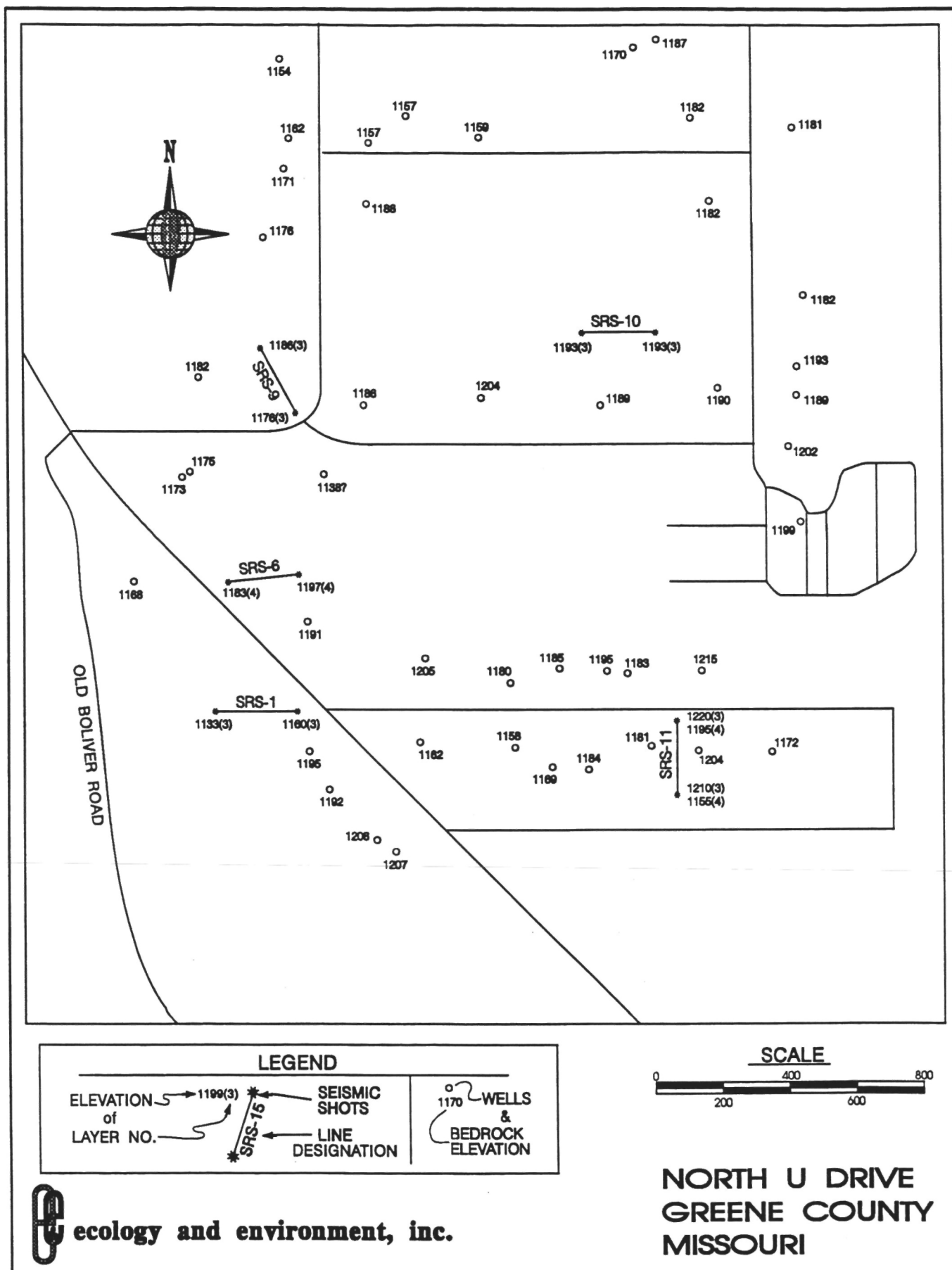
**LAYER VELOCITIES FROM SEISMIC DATA**

SEISMIC LINE	VELOCITIES (Feet Per Second)			
	LAYER 1	LAYER 2	LAYER 3	LAYER 4
SRS - 1	727	2,286	5,642	N.D.
SRS - 2	N/R	N/R	N/R	N/R
SRS - 3	620	10083 & 2072	N.D.	N.D.
SRS - 4	N/R	N/R	N/R	N/R
SRS - 5	N/R	N/R	N/R	N/R
SRS - 6	615	1,095	N.D.	10,384
SRS - 7	640	1,391	N.D.	9,042*
SRS - 8	692	1,818	3,870	N.D.
SRS - 9	660	2,264	4,996	N.D.
SRS - 10	N.D.	1,065	5,945	N.D.
SRS - 11	625	1,318	3,858	8,159

\* Probable water line

N.D. = Not Detected

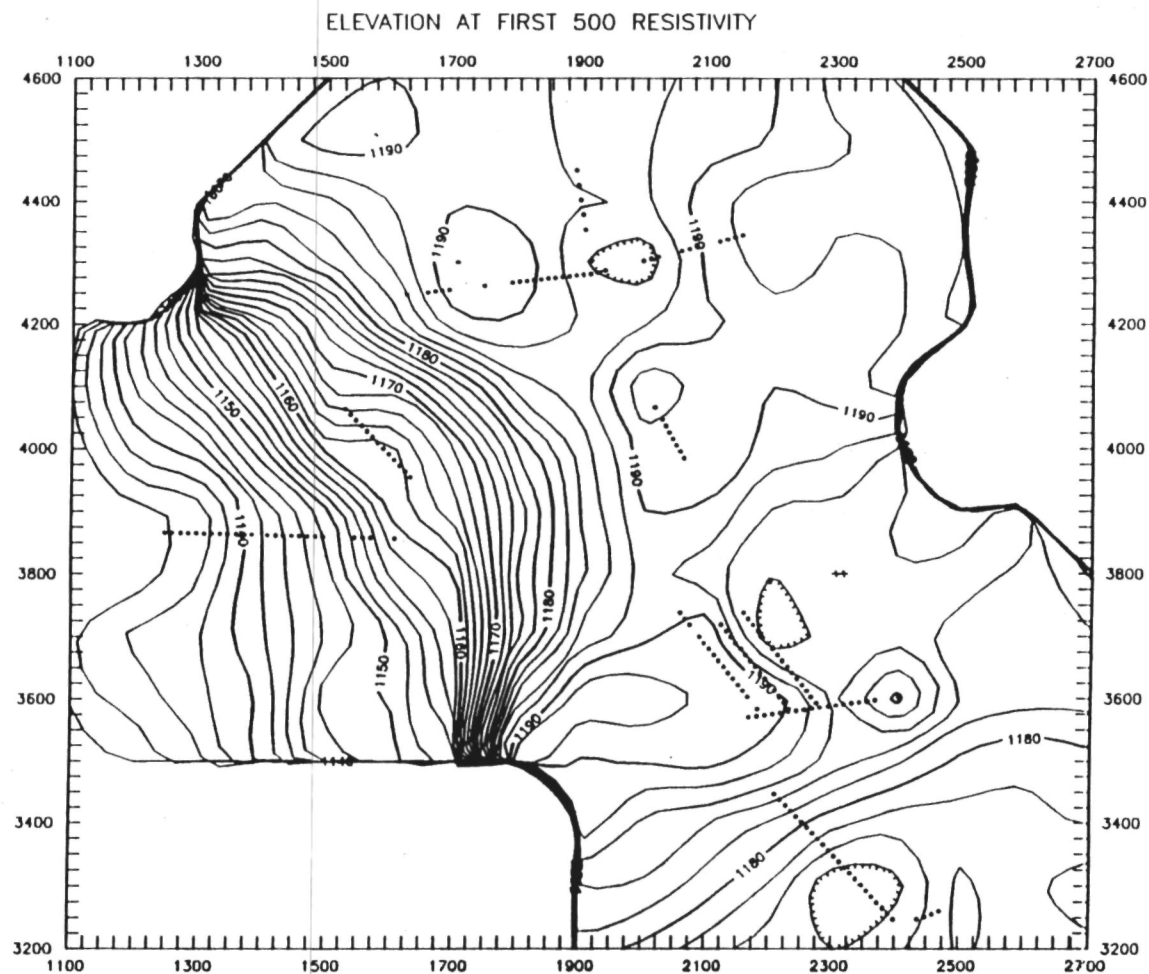
N/R = Non-Reduceable



Prepared By: L.J.Baer

January, 1991

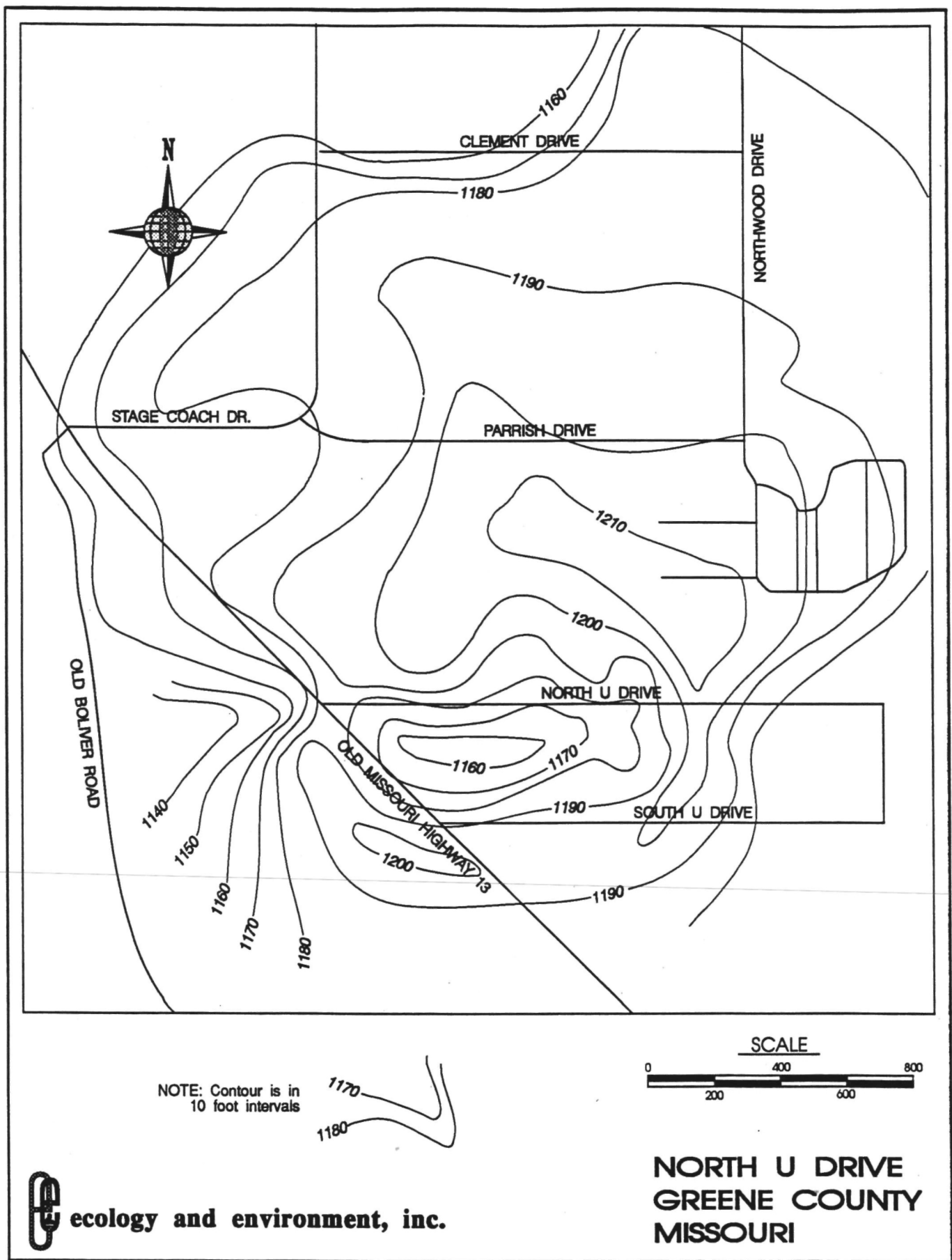
Figure 3.3-3: BEDROCK ELEVATIONS



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Figure 3.3-4: RESISTIVITY CONTOUR MAP:  
ELEVATIONS AT 500 ohm-Feet



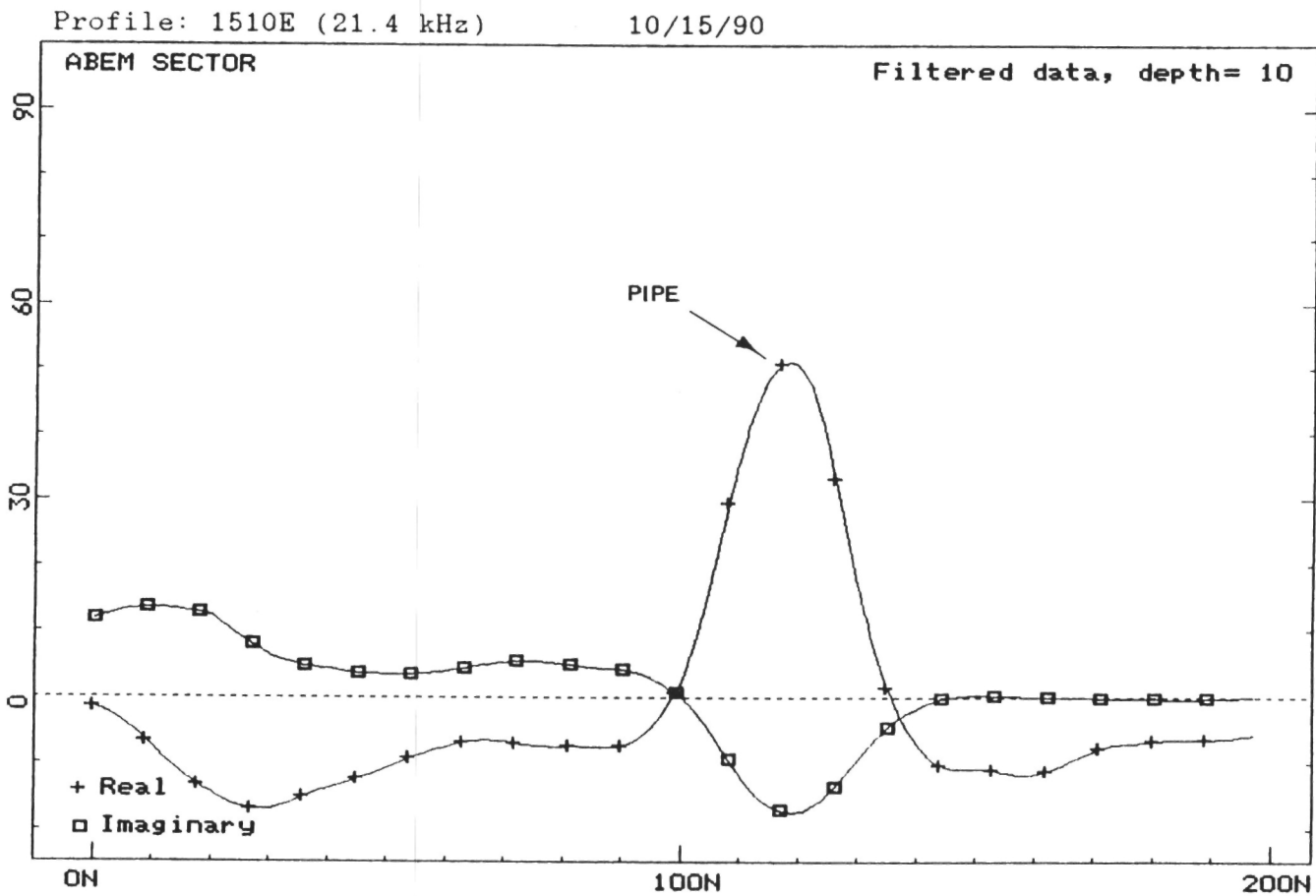
**Figure 3.3-5: BEDROCK TOPOGRAPHY CONTOUR MAP**

resistivity increases sharply. Each of these conditions are most apparent: on cross-sections for resistivity survey lines DDR-2, DDR-5 and DDR-8. Appendix B-2 contains a resistivity pseudo cross-section for each resistivity survey line.

Together, these zones of apparent resistivity reversals and anomalous high values indicate a northwest-southeast trend which may reflect a path of preferential migration for fluids. Joint and fracture trends often occur in sets, with approximately perpendicular orientations. Therefore, assuming the resistivity anomalies represent one of a pair of such trends, it could be expected that a northeast-southwest path of preferential flow also exists. Although there was not as much geophysical evidence of this second trend, surface drainage features indicate it may actually be a dominant one near the study area.

The primary evidence is an array of four sinkholes, two of which are within the study area, that line up approximately N.50°E. (These are the trailer park and Coble sinkholes, a small filled sinkhole in the trailer park, and a much larger sinkhole located outside of the study area, about 400 feet northeast of the Coble sinkhole.) In many karst areas, solution work along joints and fractures results in sinkhole development in such a linear fashion. Occasionally, sinkholes may coalesce to form larger depressions.

It was hoped that the VLF method would indicate these same types of fracture zones or conduits. However, the potentiometric surface of the shallow aquifer was below the investigation depth of the VLF (approximately 50 feet at this site) over the entire study area. The VLF technique is designed to identify highly conductive subsurface features which, in most cases, requires that the fractures, conduits, or other water catchment targets be water-filled. All substantial anomalies in the VLF data were interpreted to have been caused by cultural features such as pipelines, overhead powerlines, and fences. An example of this is shown in Figure 3.3-6 where VLF line 1510E has a large anomaly at station 120 N. This anomaly was later found to be a water supply pipe from the well that used to service the mobile home court and rental homes along Parrish Drive.



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Figure 3.3-6: VLF DATA PROFILE

Profiles and pseudo cross-sections of all VLF single profile lines, as well as a stacked profiles display of the data collected from the former Curtis service station grid, are included in Appendix B-3.

### 3.4 SOILS

The North U Drive site is situated upon flat to rolling uplands exhibiting gentle to moderate slopes. Soils in this area have developed as a residuum from the weathering of the underlying cherty limestone. Soil mantle ranges from red colored clayey soil to layers of chert boulders and gravel containing very little clay. In some areas soil sequences may be as thick as 30 feet and contain very little chert. In other areas, there may be sequences of chert boulders and gravel layers one to four feet thick, separated only by a thin layer of clay. The large amount of chert gravel in this residuum soil increases its permeability. A layer of chert gravel, or a relict chert bed which has numerous fractures, may be an avenue for rapid lateral movement of water and contaminants (MDNR 1978).

Soils in the study area are classified by the USDA system as the Goss-Wilderness-Peridge Association. Generally, these soils are deep, well drained to moderately well drained. These soils are found on gently sloping to moderately steep slopes, on uplands and terraces.

The major soil type at the site is the Wilderness. The Wilderness soils are typically found on gentle slopes. Other soil units found in the area are the Goss Cherty Silt Loam, found on steep side-slopes along the Dry Sac River to the East and along the southern portions of the site; and the Peridge Silt Loam, found along stream beds and intermittent drainage pathways (USDA 1982).

At the surface, the Wilderness soils are a very dark grayish brown cherty silt loam about 5 inches thick; and a subsurface layer is brown and grayish brown, very cherty silt loam about 11 inches thick. These soils are classified as silty sand to a clayey sand (SM-SC), clayey sand (SC), sand to a clay sand (SP-SC), and clayey gravel (GC) under the Unified Soil Classification System (USCS). The subsoil above the fragipan is brown, friable very cherty silty clay loam (sand to a clayey sand

SP-SC) about 8 inches thick. This USCS classification is clayey gravel (CG), gravel to a clayey gravel (GP-GC), clayey sand (CS) and sand to a clay sand (SP-SC). The fragipan is a multicolored firm very cherty silty clay loam [silty gravels to a clayey gravel (GM-GC), clayey gravel (GC), clayey sand (CS), and sand to clayey sand (SP-SC), about 10 inches thick]. Finally the subsoil below the fragipan is a dark red, very firm cherty clay to a depth of 64 inches. The USCS classification is clayey gravel and gravel to a clayey gravel (GP-GC).

Typically, the Goss soil has a surface layer of very dark grayish brown cherty silt loam, silt (ML), clay (CL) and clay to a silt (CL-ML) about 8 inches thick. The subsoil to about 60 inches is brown friable cherty silty clay loam above to a yellowish red firm cherty silty clay loam near the middle, and a dark red, very firm cherty clay at depth. The USCS classification is a silty gravel (GM), clayey gravel (GC) and silty gravel to a clayey gravel (GM-GC) grading to a clayey gravel (GC).

The Wilderness soils have moderate permeabilities near the surface, but become less permeable at the fragipan. Permeabilities range from  $4.2 \times 10^{-4}$  cm/sec to  $4.2 \times 10^{-3}$  cm/sec at the surface, dropping to as low as  $4.2 \times 10^{-5}$  cm/sec at the fragipan. Below the fragipan permeabilities increase slightly. The liquid limit (LL) ranges from 20 to 40 and the plasticity index (PI) ranges from 5 to 20. Moist bulk densities range from 1.20 to 1.70 g/cm<sup>3</sup>; however, the fragipan ranges from 1.70 to 2.00 g/cm<sup>3</sup>.

Permeabilities of the Goss soils are in the same ranges as the Wilderness soils. However, the liquid limit ranges from 20 to 30 in the upper soils, and 50 to 70 in the subsoil. The PI ranges from 2 to 8 near the surface and 30 to 40 at depth. Bulk densities are in the range of 1.10 to 1.30 g/cm<sup>3</sup> at the surface and 1.30 to 1.50 g/cm<sup>3</sup> at depth.

Peridge soils are deep, gently sloping and well drained. Typically, the surface layer is a brown silt loam [silt (ML) to a clayey-silt (CL-ML)] to about 9 inches. The subsoil extends to 72 inches and is reddish brown, friable and yellowish red firm silty clay loam [clay (CL)]; grading to red mottled, firm silty clay loam [clay (CL) to clayey

sand (SC)] in the middle; to a dark red, mottled, very firm cherty clay [clay (CL), sandy clay (SC) to a gravely clay (GC)] at depth.

The LL ranges from <20 at the surface to 50 at depth and the PI ranges from non-plastic at the surface to 25 at depth. Permeabilities range from  $4.2 \times 10^{-3}$  cm/sec to  $1.41 \times 10^{-3}$  cm/sec.

### 3.5 DEMOGRAPHY AND LAND USE

North U Drive is situated in a small predominantly residential area surrounded by a rural setting. The approximate boundaries of the study area are North Stage Coach Road, to the north, the Little Sac River to the east, New Highway 13, to the west, and the south property line of Montgomery Metal Craft, to the south. The surrounding area is subject to a mixture of land uses. To the north is a quarry, woodlands and pasture land. The former Fulbright landfill site, which is also a former NPL site, is located to the north-northeast. The former Northwest Wastewater Treatment Plant, the Springfield Animal Shelter, a police department firing range, the Fulbright Spring and the Fulbright Water Treatment Plant are all located east-northeast of the study area. The Little Sac River and Pea Ridge Creek flow between the site and the city facilities mentioned above. However, a municipal water reservoir is situated just east of the study area, between its eastern boundary and Pea Ridge Creek. To the south and west, the area is predominantly rural and agricultural, though new housing developments are being constructed to the west of new Highway 13.

Several businesses are located within the study area. A small automotive body shop is located in the north central portion of the site, on the Degraffenreid property. Frazier Brothers Construction Company, an electrical contractor, is located near the center of the study area. At the south central portion of the study area, Montgomery Metal Craft maintains a plant and storage area for storage tank rehabilitation. Finally, there are three abandoned gasoline service stations located along Old Highway 13, between South U Drive and Stage Coach Drive.

The City of Springfield, Missouri has shown consistent growth recent years. The 1980 population was 133,116. The preliminary 1990 data shows a population of 139,409. The city serves an even larger metropolitan area of 234,300 (1988 data). Approximately 200 to 300 people live within 1/4 mile of the study area (USDOC 1988; USDOC 1990).

### 3.6 SUBSURFACE SOURCE CHARACTERISTICS

As discussed in Section 2.2 of this report, terrain conductivity and magnetic field surveys were conducted at five sites regarded as potential sources for the groundwater contamination within the study area. These surveys were intended to characterize shallow subsurface conditions at each site, specifically to identify suspicious burials which would then be flagged for soil-gas investigation.

At the Coble sinkhole, no significant burials were identified and the source investigation was limited to a reconnaissance, (i.e., no formal survey grid was established). However, two small anomalies, presumably associated with a former storage shed which once stood on the western flank of the sinkhole, were identified and flagged for soil-gas sampling.

Reconnaissance of the sinkhole located west of the Mobile Gardens trailer park indicated this depression has been filled, approximately to natural grade, with miscellaneous debris. As discussed in Section 2.2, a grid survey over this area would have been an impractical endeavor. Instead, the EM-31 and magnetometer were used to locate five discrete, very shallow (less than five feet) metal objects. These locations were then flagged as potential soil-gas sample points.

Reconnaissances at the three former service stations identified significant, discrete anomalies at each location. Grid surveys were performed at these properties to better characterize the anomalies for interpretation.

#### Former Five Gables Service Station

Figures 3.6-1 and 3.6-2 are contours of the total magnetic field strength and terrain conductivity, respectively, over a portion of the

former Five Gables service station. An outline of the survey area is represented as Grid No. 1 on Figure 2.2-1.

A magnetic field anomaly is present in the center portion of the grid. This anomaly reflects a typical dipolar burial which induces both an addition and subtraction to the normal magnetic field strength. At mid-latitudes in the northern hemisphere, the subtraction, or magnetic low occurs north of the buried object while the addition, or magnetic high, occurs directly south of the burial.

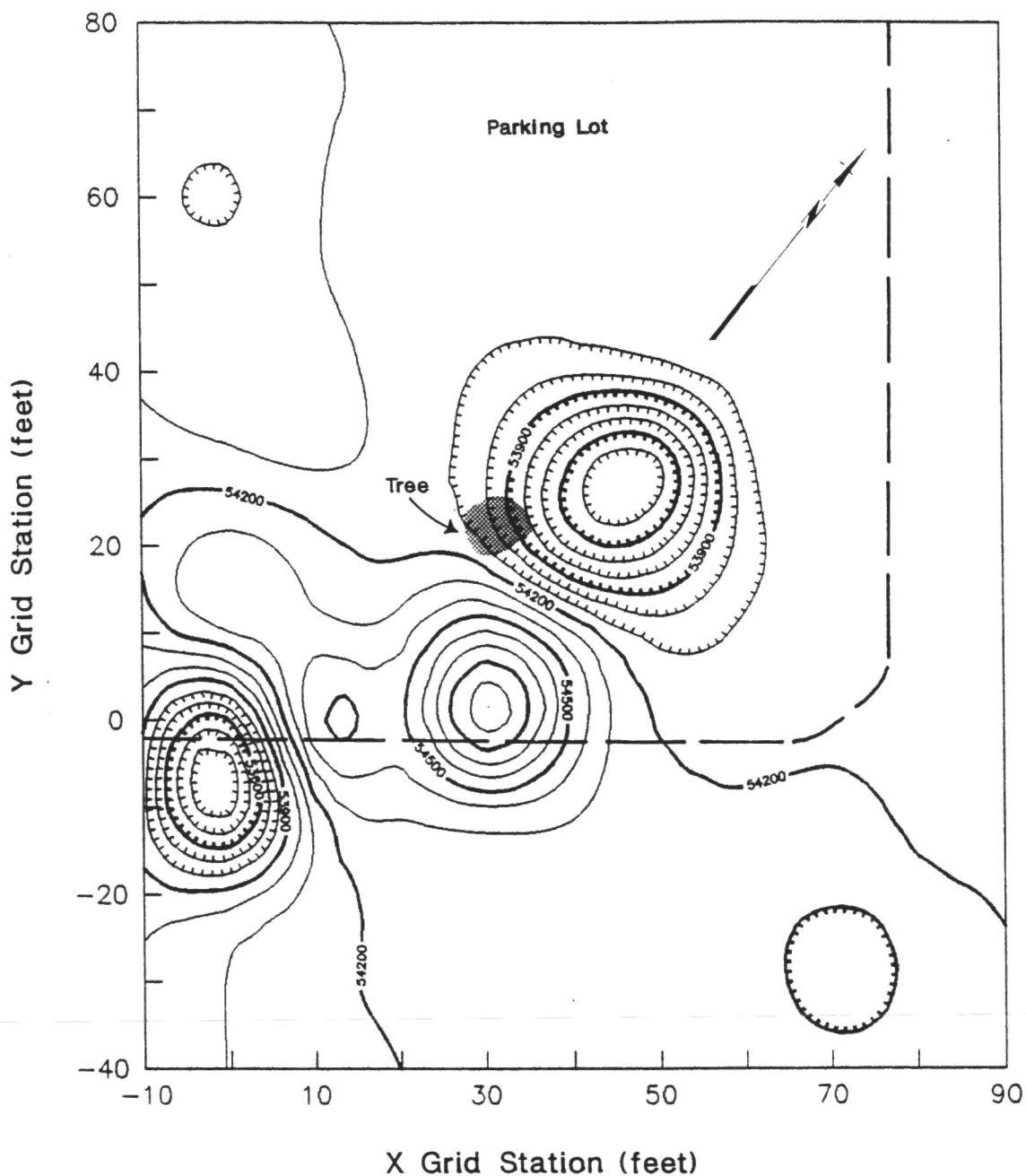
The position of the object is more accurately confirmed by a depression in terrain conductivity centered at station +40 NE, +20 NW. As mentioned in Section 2, the presence of shallow metal objects causes a negative response on the EM-31. However, in this instance the EM-31 readings did not drop below zero, indicating the object(s) is probably at least four or five feet deep.

This anomaly is situated within an area where above-ground gasoline tanks once stood. This service station supposedly did not have any underground tanks, and the physical and spatial magnitude of the anomaly suggests the object is something smaller than a typical (1,500 + gallons) underground gasoline tank. The possibility does exist that the object(s) is a smaller tank, though it is more likely something related to the operation of the above-ground tanks, perhaps a pump.

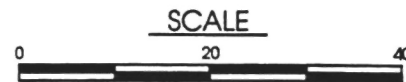
Figure 3.6-1 shows an additional, negative anomaly in the lower left-hand (southern) corner of the grid. This signature is the result of a large, electric sign located at that position. The terrain conductivity data (Figure 3.6-2) also reflects the presence of this sign as well as the conduit which runs northward, from the signpost towards the bookstore.

#### Former Derby Service Station

Figures 3.6-3 and 3.6-4 are total magnetic field strength and terrain conductivity contours over the entire Derby service station lot (now owned by Coastal Mart). This survey area is represented as Grid No. 2 on Figure 2.2-1. All structures on the facility have been razed and the surface was relatively free of cultural obstacles.



Contour Interval= 100 gammas  
Survey Conducted on October 10, 1990



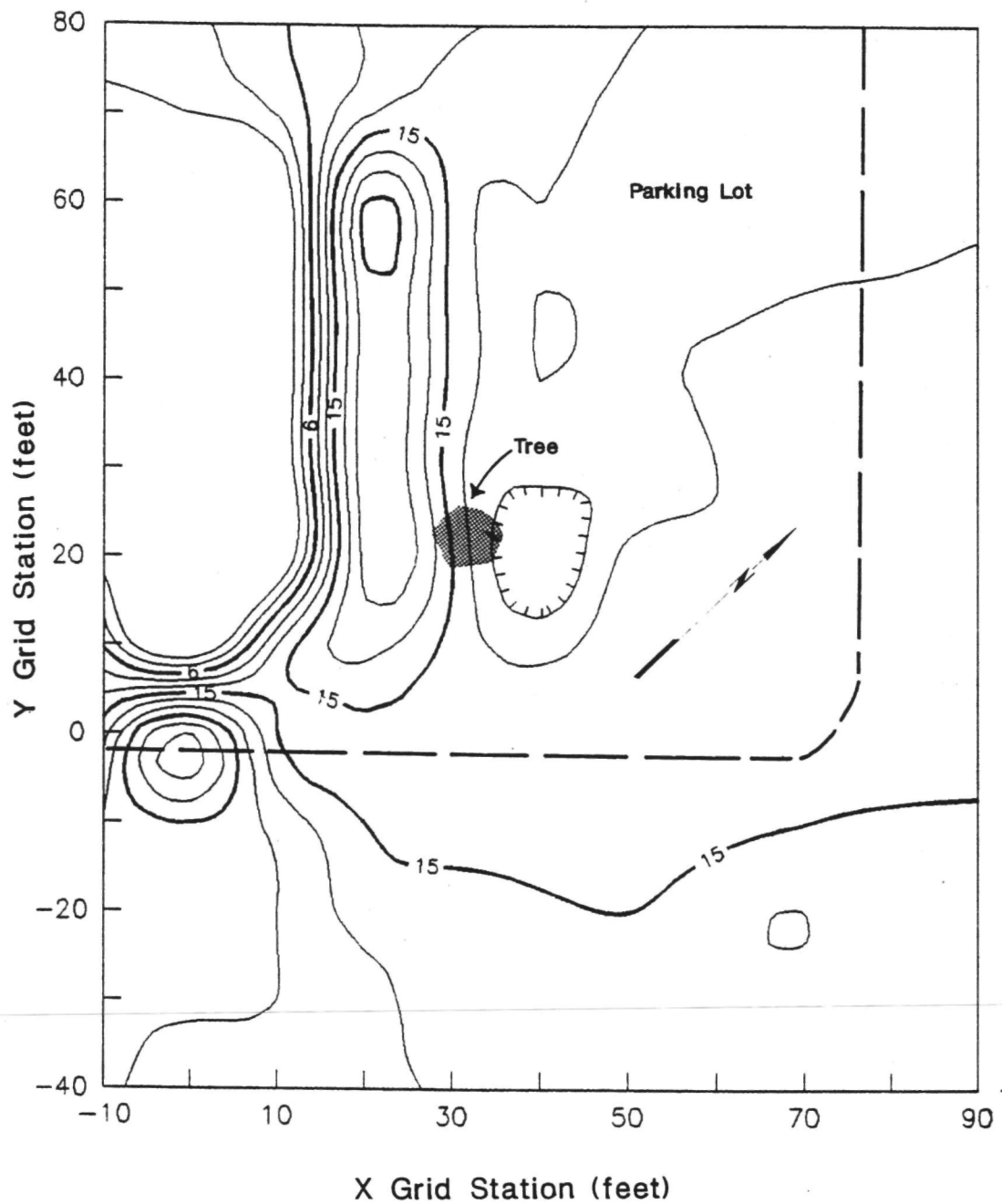
 **ecology and environment, inc.**

**NORTH U DRIVE  
GREENE COUNTY  
MISSOURI**

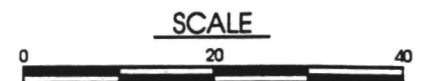
Prepared By: Lee Robertson

January, 1991

**Figure 3.6-1: TOTAL MAGNETIC FIELD SURVEY  
FORMER FIVE GABLES SERVICE STATION**



Contour Interval= 3mmhos/meter  
Survey Conducted on October 10, 1990



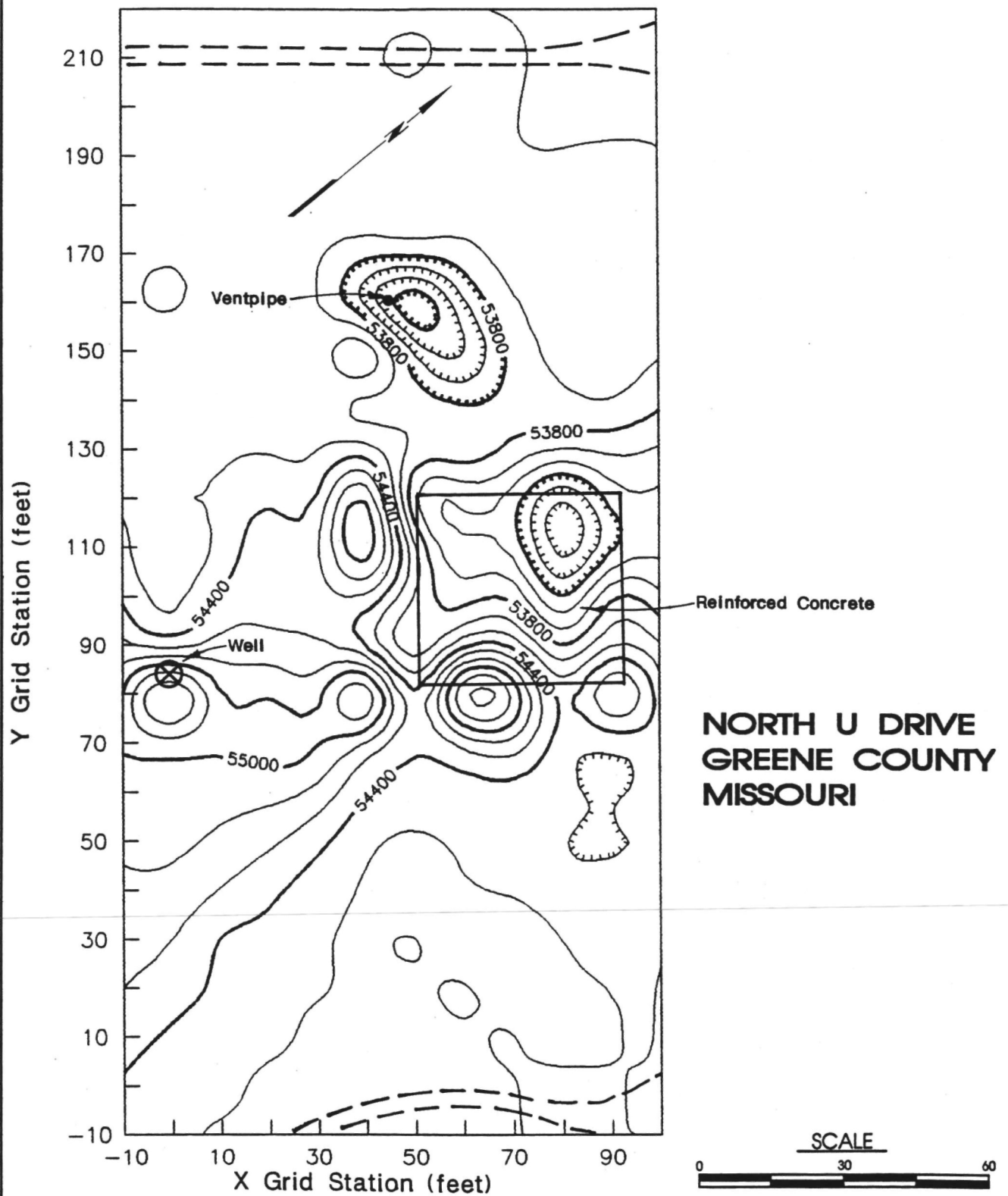
 **ecology and environment, inc.**

**NORTH U DRIVE  
GREENE COUNTY  
MISSOURI**

Prepared By: Lee Robertson

January, 1991

**Figure 3.6-2: TERRAIN CONDUCTIVITY SURVEY  
FORMER FIVE GABLES SERVICE STATION**



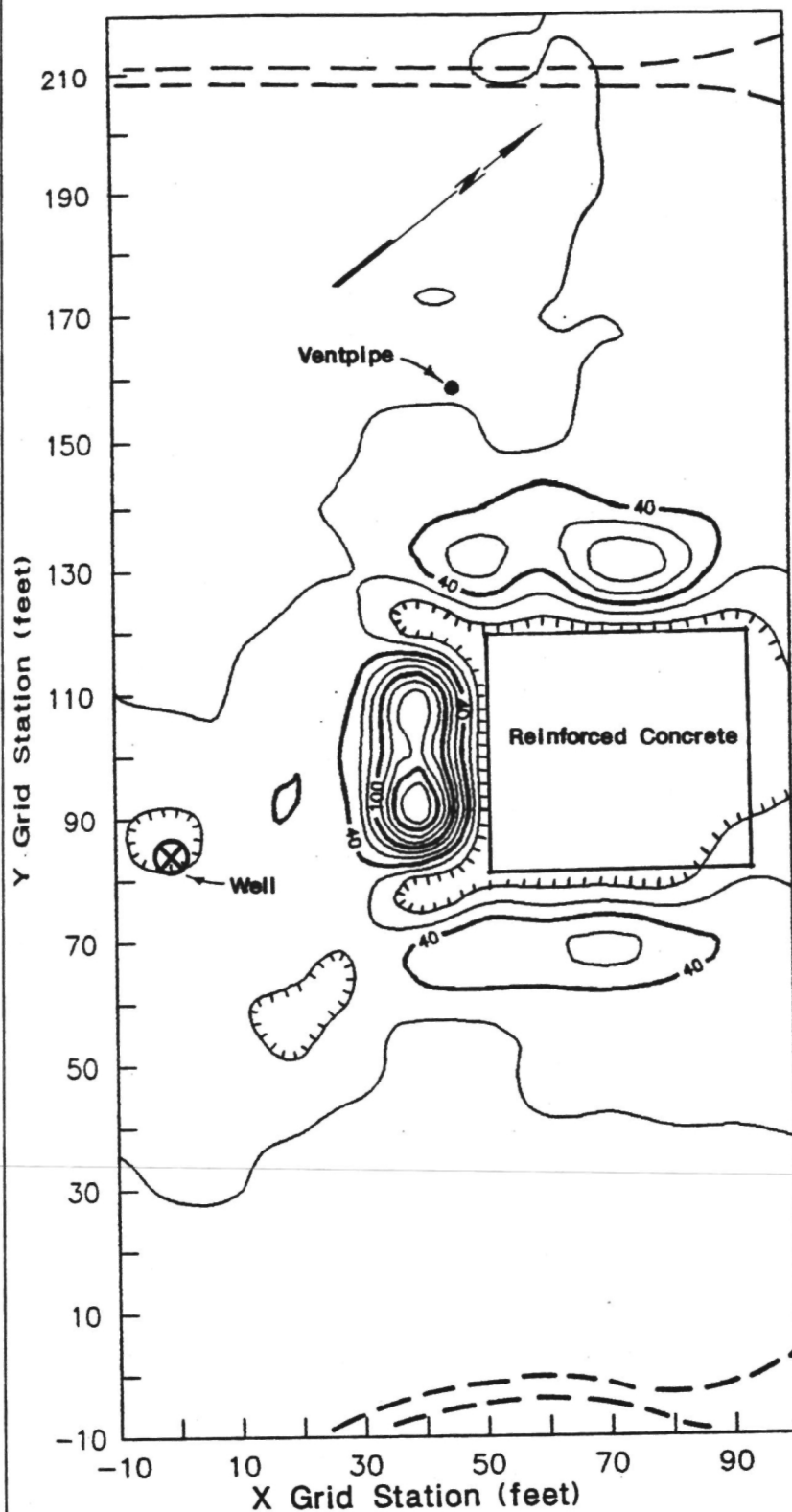
**ecology and environment, inc.**

Contour Interval= 20 mmhos/meter  
Survey Conducted on October 9, 1990

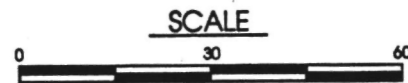
Prepared By: Lee Robertson

January, 1991

**Figure 3.6-3: TOTAL MAGNETIC FIELD SURVEY  
FORMER DERBY SERVICE STATION**



**NORTH U DRIVE  
GREENE COUNTY  
MISSOURI**



**ecology and environment, inc.**

Contour Interval= 200 gammas  
Survey Conducted on October 9, 1990

Prepared By: Lee Robertson

January, 1991

**Figure 3.6-4: TERRAIN CONDUCTIVITY SURVEY  
FORMER DERBY SERVICE STATION**

The magnetic field contours show at least one anomaly which may represent an underground storage tank. The magnetic low is centered at station +85 NE, +115 NW and the magnetic high is centered at station +65 NE, +80 NW. In this case, the magnitude of the total field strength adjustment is close to what one may expect over an underground storage tank. Because this portion of the lot is paved with reinforced concrete, the conductivity data cannot confirm the magnetic anomaly. The re-bar induces negative responses from the EM-31 so that no further interpretation of the subsurface (beneath the re-bar) is possible. However, if an underground tank does exist at this site, it would likely be located beneath the reinforced concrete pad, as the magnetic data suggests. (The re-bar will also affect the magnetic field to a lesser degree.)

A large magnetic low is centered at station +50 NE, +160 NW, very near a vent pipe which apparently has been left in its original position. However, there does not appear to be a magnetic high associated with this anomaly, and the magnetic fluctuation is likely a reflection of the standpipe.

An intense conductivity gradient is apparent near the center of the grid, where the service station building once stood. A fairly significant magnetic high occurs over the same approximate area. The source of these anomalies is likely related to the former structure, but is not likely to be a tank. Additional, less significant, anomalies were induced by surficial interferences within the survey area.

#### Former Curtis Service Station

Figures 3.6-5 and 3.6-6 are contours of the total magnetic field strength and terrain conductivity, respectively, over the former Curtis service station property. An outline of this survey area appears as Grid No. 3 in Figure 2.2-1.

The service station was actually located within the northwestern corner of this property. However, this site is particularly suspect in



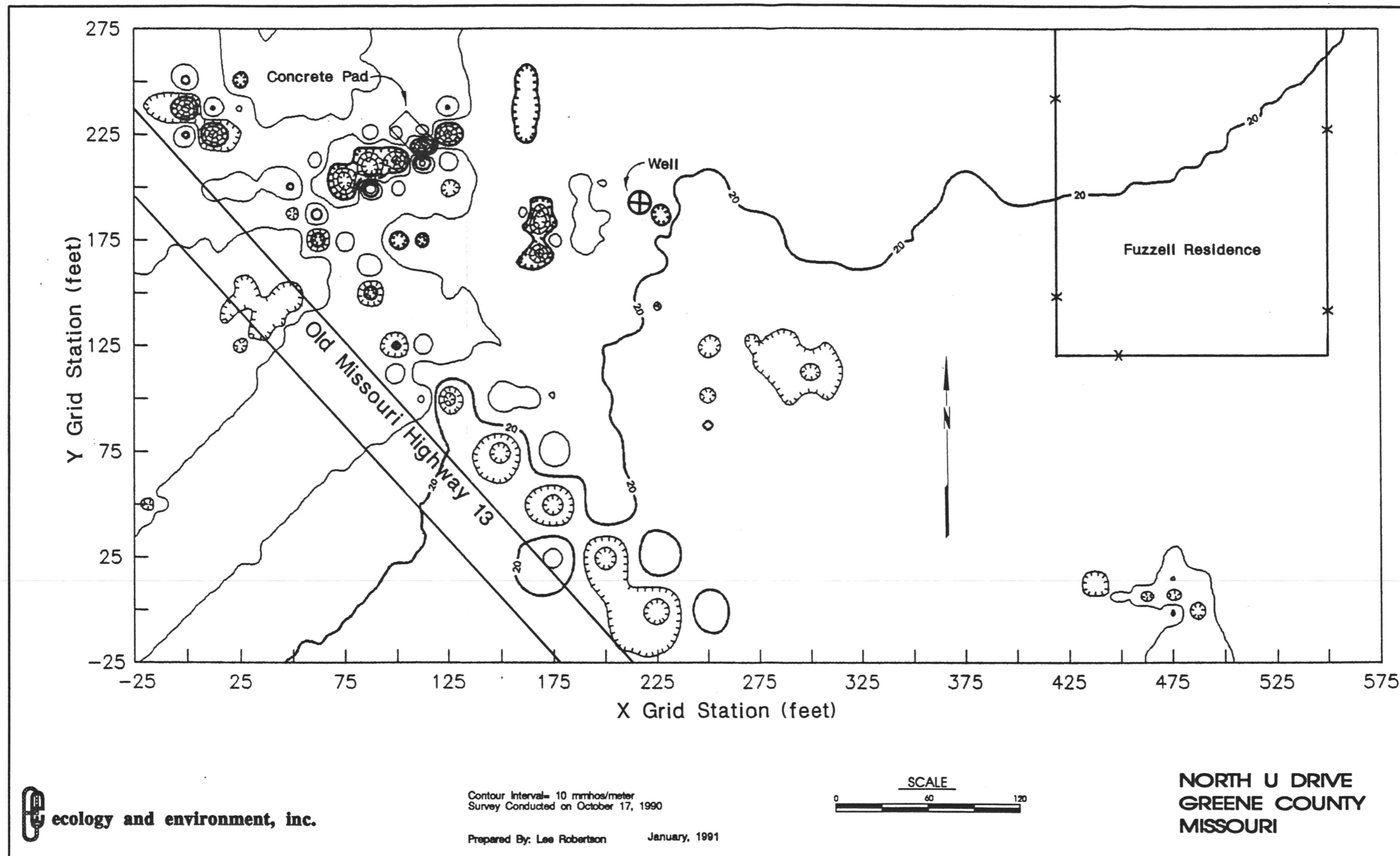


Figure 3.6-6: TERRAIN CONDUCTIVITY SURVEY  
FORMER CURTIS SERVICE STATION

this investigation due to the gross contamination which had been identified in a well located near the center of the property. It was, therefore, decided to examine the entire area for potential buried sources.

High conductivity and magnetic field gradients along the southwestern border of the grid reflect underground utility (gas and water) lines running along the east side of Old Highway 13, between South U Drive and North U Drive. An additional interference, in the form of a steel, military tank-type vehicle, was encountered in the extreme northwestern corner of the property. This obstacle is reflected as a large magnetic depression, centered approximately at station +50 E, +225 N. (EM-31 readings were not collected near the tank.)

Further east, towards the former service station, additional anomalies exist which cannot be explained by utility lines or surficial influences.

A series of conductivity depressions, indicating shallow metal burials, occur near a concrete slab that is located within the area where the former station once stood. A small magnetic anomaly occurs in the same area, though, based upon its geometry, it appears to support only one of the conductivity anomalies. As none of these anomalies are supported by a strong magnetic gradient, the source(s) is either highly decayed or has a relatively small mass.

Further to the east, near the center of the property, two large magnetic peaks occur side-by-side. The eastern peak, centered approximately at station +215 E, +185 N, correlates with an old well known to be near that exact location (about one foot of the well casing sticks up above the surface). This magnetic anomaly, unlike most of the others discussed thus far, reflects a typical monopole burial in which only an addition to the normal magnetic field strength occurs. In this example, the well casing behaves as an infinitely long dipole so that only the end at or near the surface affects the field gradient.

Another monopole anomaly exists directly to the west, its center at station +185 E, +185 N, nearly 30 feet from the above referenced well. The possibility exists that another well exists here, though there is no evidence of this at the surface or in the historical information. In

addition, a conductivity trough occurs immediately west of this latter magnetic peak. The conductivity values indicated that a buried metallic object, with its long axis oriented approximately north-south, runs along the western edge of the magnetic anomaly. Based upon the magnetic response over the conductivity anomaly, it would not appear that this object is a tank, as tanks generally, but not always, appear as dipolar anomalies. (If the object has decayed or oxidized significantly, the geometry of the anomaly will also change.)

One, final, anomalous area was identified in the southeastern corner of the property. This burial, though relatively small, was identified as both a dipolar magnetic anomaly and a conductivity trough. There are no underground utilities in this area and there are no clues as to what may have been buried here.

Most of the anomalies identified during the shallow subsurface investigation were further characterized by one or two nearby soil-gas samples. The results of these samples may or may not indicate the need for further, perhaps physical, examination of the defined burial areas during Phase 2. Field data sheets and survey grids, illustrating the data point configurations, are included in Appendix B-4.

#### 4. NATURE AND EXTENT OF CONTAMINATION

##### 4.1 VADOSE ZONE AND SOIL SAMPLING

The vadose zone and soil investigations conducted in this phase included a soil-gas survey and shallow subsurface soil sampling. These investigations produced 87 soil-gas samples, nine soil samples, and one water rinsate. Appendix D presents the waste characteristics for the chemical compounds found during the soil and soil-gas investigations. The analytical data was utilized to evaluate the potential sources found during the background data gathering task and to define whether a broader range of contaminants (volatile organic compounds, semi-volatiles, metals, and cyanide) may be present. This data, will be used to plan necessary activities under Phase II.

##### 4.1.1 Data Evaluation

This portion of the Phase 1 Final Report describes how the soil and vadose zone data was evaluated. The focus of this section is predominately on analytical data, since this data is required to be of litigation quality. The previously submitted Quality Assurance Project Plan (QAPP) states that only analytical data which has undergone data validation and has been found acceptable will be utilized to draw conclusions for planning the Phase 2 portion of the remedial investigation. The soil sampling results are preliminary data provided by the Ecology and Environment, Inc. (E & E) Analytical Services Center Laboratory, in Buffalo, New York. This EPA Contract Laboratory Program (CLP)-quality data is in the process of being validated by the Missouri Department of Natural Resources (MDNR). Therefore, it will be used for preliminary conclusions and recommendations pending data validation.

The soil-gas data has been validated by the E & E regional Field Analytical Screening Program (FASP) coordinator and found to be of quality for use as Level II data, as defined in the data quality objectives.

Data from ancillary field instrumentation (i.e., data from geophysical instrumentation, pH meters, and specific conductivity meters) necessary for project planning and direction of field activities has also been evaluated in a similar fashion.

Upon receipt of CLP data, all field analytical results were compared to the field Quality Control (QC) samples (trip blanks, field blanks, and rinsates). This allowed the investigation team to determine if any field conditions or procedures caused interference with the environmental samples. Definitions of these QC samples are provided in the QAPP.

Sample results which were found to be above analytical detection limits are summarized and tabulated along with any qualifiers. The tables also include a legend at the bottom which defines these qualifiers. For the compound detected below the detection limit a "less than" (<) sign was used, and the detection limit was still tabulated, for example <5.0. The tables also include a legend at the bottom which defines these qualifiers. In addition to the data summary tables provided, the invalidated CLP data package is also included as Appendix C-1. However, due to the volume of information, the full CLP package is not included.

Field and calibration data obtained from monitoring instrumentation were recorded in the field logbooks. This data is briefly discussed in Subsection 2.3 and is not tabulated.

Soil gas data generated by field analytical instrumentation (gas chromatography) were subject to the appropriate E & E Standard Operating Procedure (SOP) for the Field Analytical Screening Program.

The Quality Assurance/Quality Control (QA/QC) data validation for the soil-gas results is attached as Appendix C-3. All data and procedures used in generation of soil-gas data was subject to the stipulations of the QAPP, as well as review by the E & E QA/QC Project Director

and Regional QA Officer. Tabulated data was independently verified against original data sheets or field notes to assure accuracy.

#### 4.1.2 Soil-Gas Survey

The primary objective of the soil-gas survey was to identify and isolate potential sources of groundwater contamination near the site. A secondary objective was to determine contaminant plumes. This second objective, dependent on the correlation between the soil-gas plume and the groundwater plume, was not documented.

The soil-gas chromatograph Level II data (as defined in the Quality Assurance Project Plan) was designed to provide information on the target compounds of the soil-gas survey. These compounds are benzene, trichloroethylene (TCE), toluene, tetrachloroethylene or perchloroethylene (PCE), ethylbenzene, and o-xylene. Some unidentifiable compounds were also recorded during the soil-gas survey these compounds presented themselves as "peaks" in the gas chromatography's strip chart. An early peak may indicate an unidentified compound which is more volatile than benzene. The compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak indicated a compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

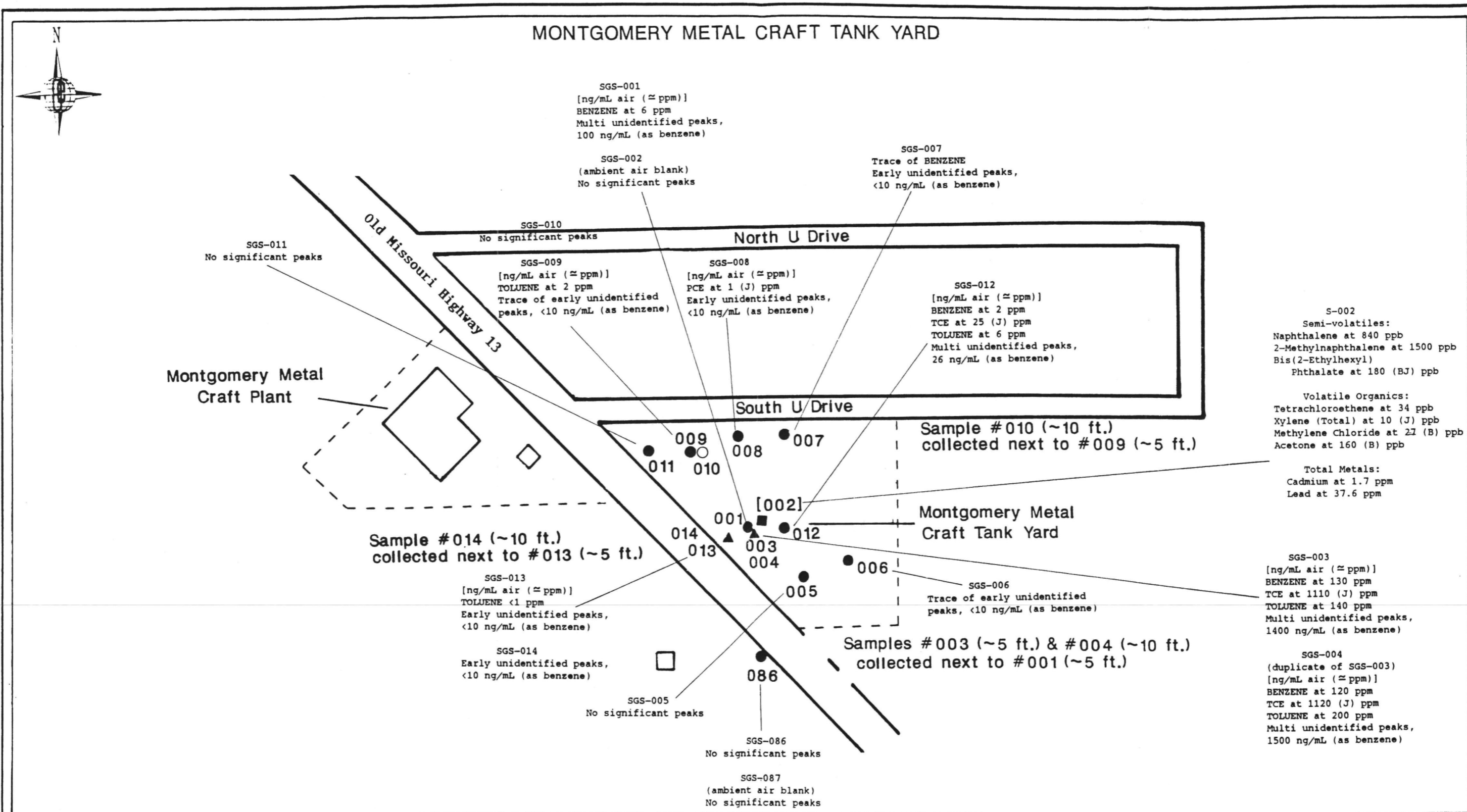
A "J" qualifier in the data indicates an estimated value. This could refer to a value for a compound which did not exhibit linear gas chromatograph detector response (TCE, PCE), or it could represent a sample analysis which exceeded the specified one-hour holding time.

A trace indicates a possible detection of the compound below one nanogram per milliliter (<1 ng/ml) of air and indicates a probable detection below the quantification limit.

The following discussion summarizes the soil-gas sampling results for each of the identified potential pollution source areas:

#### Montgomery Metal Craft Tank Yard

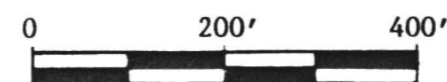
The soil-gas investigation produced 16 soil-gas samples at the Montgomery Metal Craft Tank Yard (Figures 2.3-1 and 4.1-1). Soil-gas



SOIL-GAS SAMPLE SERIES MG2016-SG-  
 001: Soil-Gas Sample Number  
 ● : Shallow Soil-Gas Sample (~5 feet)  
 ○ : Deep Soil-Gas Sample (~10 feet)  
 ▲ : Shallow and Deep Soil-Gas Samples

SOIL SAMPLE SERIES MG2014-S-  
 [001]: Soil Sample Number  
 □ : Residence or Other Structure  
 ■ : Soil Sample (~5 feet)

Scale 1 inch = 201.59 feet



PROJECT NUMBER: MG2018

results are summarized in Table 4.1-1. Samples numbers were from 001 through 014 and samples 086 and 087. One duplicate sample (004) and two ambient air (002 and 087) blank samples were collected for QA/QC.

Benzene concentrations ranged from non-detected to 6 ng/mL. TCE ranged from non-detected to 1120 (J) ng/mL. Toluene concentrations ranged from non-detected to 200 ng/mL. PCE concentrations range from non-detected to 1 ng/mL. Ethylbenzene and xylene were not detected in any sample location at this site. Early unidentified peaks at <10 ng/mL (as benzene) were detected in six sample locations. Multi unidentified peaks ranged from 26 ng/mL to 1500 ng/mL (as benzene).

#### Former Five Gables Service Station

The soil-gas investigation produced seven soil-gas samples at the former Five Gables service station, (Bolivar Road Bookstore), Figures 2.3-1 and 4.1-2). Soil-gas results are summarized in Table 4.1-2. Sample numbers were from 015 through 021. One field equipment (020) and one ambient air (021) blank sample were collected for QA/QC purposes.

Benzene concentrations ranged from non-detected to <1 ng/mL. TCE concentrations ranged from non-detected to 9 (J) ng/mL. Toluene concentrations ranged from non-detected to 2 ng/mL. PCE, ethylbenzene and xylene were not detected in any sample location at this site. Early unidentified peaks at <10 ng/mL (as benzene) were detected in four sample locations. Multi unidentified peaks was detected at <10 ng/mL (as benzene).

#### Mobile Gardens Trailer Park Sinkhole

The soil-gas investigation produced six soil-gas samples at the Mobile Gardens Trailer Park Sinkhole (Figures 2.3-1 and 4.1-3). Soil-gas results are summarized in Table 4.1-3. Sample numbers were from 022 through 027. No field equipment or ambient air blank samples were collected at this location.

Toluene concentrations ranged from non-detected to 4 ng/mL. Ethylbenzene concentrations ranged from non-detected to 1 ng/mL. Benzene, PCE, TCE and xylene were not detected in any sample location at this

TABLE 4.1-1

SOIL-GAS DATA FOR NORTH U DRIVE  
MONTGOMERY METAL CRAFT TANK YARD  
SPRINGFIELD, GREENE COUNTY, MISSOURI  
ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
SERIES MG2016-SGS  
(CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL-BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-001	10/13/90	1	6	N.D.	N.D.	N.D.	N.D.	N.D.	Multi unidentified peaks, 100 ng/mL (as benzene)
SGS-002	10/13/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (ambient air blank)
SGS-003	10/13/90	1	130	1110(J)	140	N.D.	N.D.	N.D.	Multi unidentified peaks, 1400 ng/mL (as benzene)
SGS-004	10/13/90	1	120	1120(J)	200	N.D.	N.D.	N.D.	Multi unidentified peaks, 1500 ng/mL (as benzene) (duplicate of sample 003)
SGS-005	10/13/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-006	10/13/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Trace early unidentified peaks, <10 ng/mL (as benzene)
SGS-007	10/13/90	1	Trace	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-008	10/13/90	1	N.D.	N.D.	N.D.	1	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-009	10/13/90	1	N.D.	N.D.	2	N.D.	N.D.	N.D.	Trace early unidentified peaks, <10 ng/mL (as benzene)
SGS-010	10/13/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-011	10/13/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-012	10/13/90	1	2	25(J)	6	N.D.	N.D.	N.D.	Multi unidentified peaks, 26 ng/mL (as benzene)
SGS-013	10/14/90	1	N.D.	N.D.	<1	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-014	10/14/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-086	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-087	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (ambient air blank)

Note: See Figures 2.3-1 and 4.1-1 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

The J flag indicates an estimated value. This could refer to a value for a compound which did not exhibit linear detector response (TCE, PCE), or it could represent a sample analysis which exceeded the specified one-hour holding time.

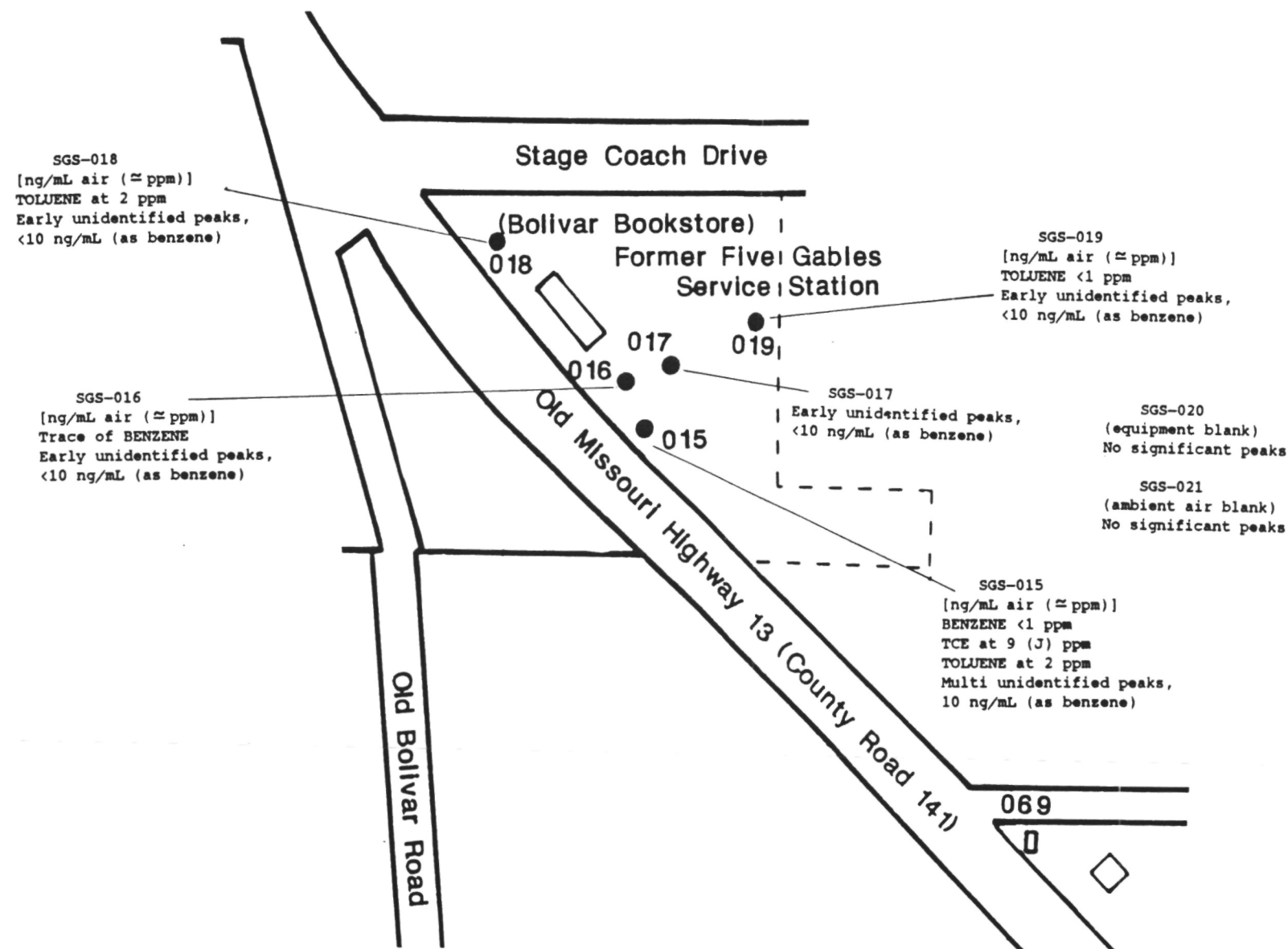
Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.



FORMER FIVE GABLES SERVICE STATION  
(BOLIVAR ROAD BOOKSTORE)



SOIL-GAS SAMPLE SERIES MG2016-SG-  
001: Soil-Gas Sample Number  
● : Shallow Soil-Gas Sample (~5 feet)  
○ : Deep Soil-Gas Sample (~10 feet)  
▲ : Shallow and Deep Soil-Gas Samples

SOIL SAMPLE SERIES MG2014-S-  
[001]: Soil Sample Number  
□ : Residence or Other Structure  
■ : Soil Sample (~5 feet)

Scale 1 inch = 201.59 feet



PROJECT NUMBER: MG2018

TABLE 4.1-2

SOIL-GAS DATA FOR NORTH U DRIVE  
 FORMER FIVE GABLES SERVICE STATION  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SERIES MG2016-SGS  
 (CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL- BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-015	10/14/90	1	<1	9(J)	2	N.D.	N.D.	N.D.	Multi unidentified peaks, 10 ng/mL (as benzene)
SGS-016	10/14/90	1	Trace	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-017	10/14/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-018	10/14/90	1	N.D.	N.D.	2	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-019	10/14/90	1	N.D.	N.D.	<1	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-020	10/14/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (equipment blank)
SGS-021	10/14/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (ambient air blank)

Notes: See Figures 2.3-1 and 4.1-2 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

The J flag indicates an estimated value. This could refer to a value for a compound which did not exhibit linear detector response (TCE, PCE), or it could represent a sample analysis which exceeded the specified one-hour holding time.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

(1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.



# MOBILE GARDENS TRAILER PARK SINKHOLE

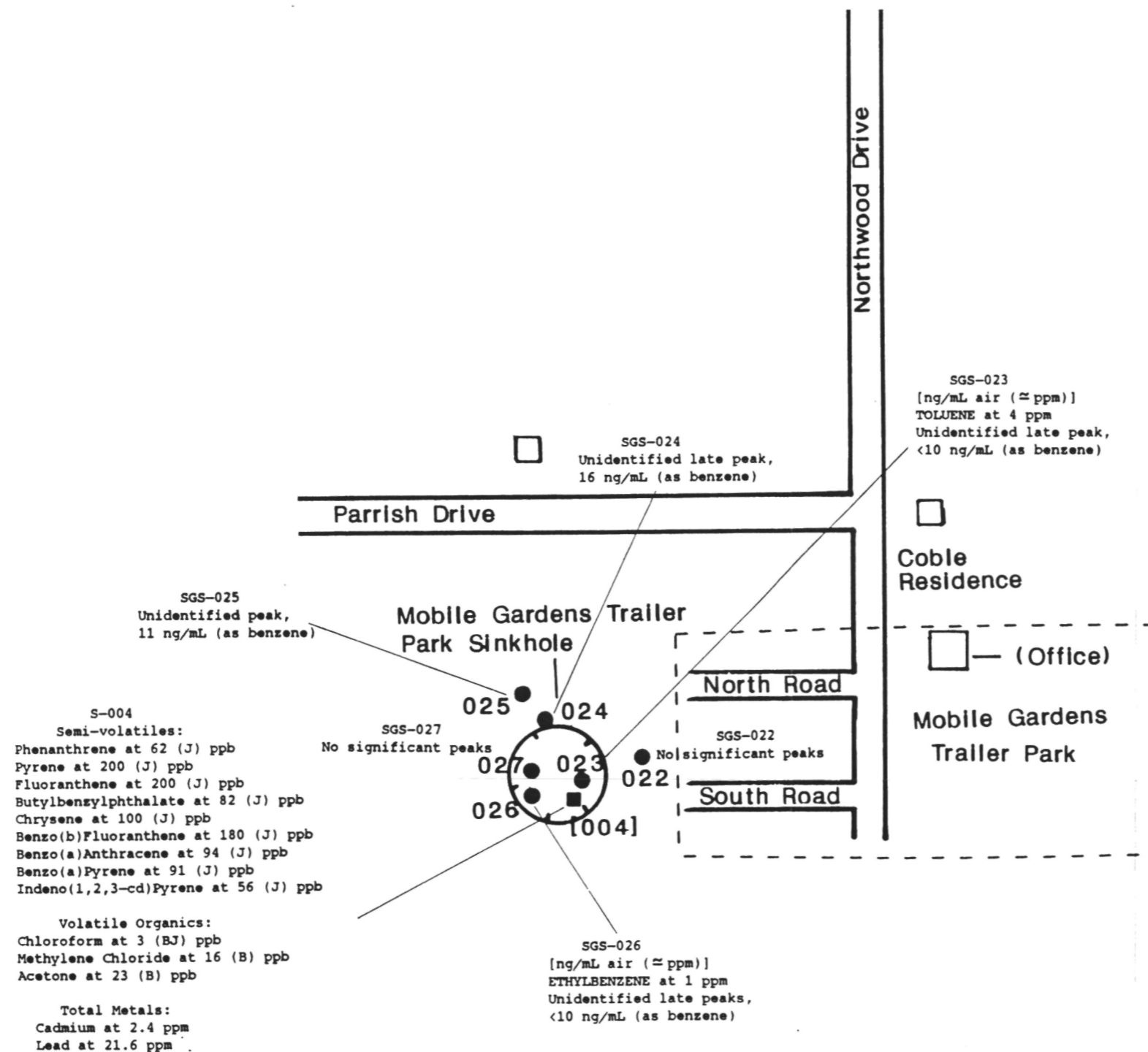


TABLE 4.1-3

SOIL-GAS DATA FOR NORTH U DRIVE  
 MOBILE GARDENS TRAILER PARK  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SERIES MG2016-SGS  
 (CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL- BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-022	10/14/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-023	10/14/90	1	N.D.	N.D.	4	N.D.	N.D.	N.D.	Unidentified late peaks, <10 ng/mL (as benzene)
SGS-024	10/14/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Unidentified late peaks, 16 ng/mL (as benzene)
SGS-025	10/14/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Unidentified peak, 11 ng/mL (as benzene)
SGS-026	10/14/90	1	N.D.	N.D.	N.D.	N.D.	1	N.D.	Unidentified late peaks, <10 ng/mL (as benzene)
SGS-027	10/15/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks

Notes: See Figures 2.3-1 and 4.1-3 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

site. Unidentified late peaks ranged from at <10 ng/mL to <16 ng/mL (as benzene).

#### Montgomery Metal Craft Plant

The soil-gas investigation produced eight soil-gas samples at the Montgomery Metal Craft plant (Figures 2.3-1 and 4.1-4). Soil-gas results are summarized in Table 4.1-4. Sample numbers were from 028 through 035. One field equipment blank sample (034) was collected for QA/QC purposes.

Benzene concentrations ranged from non-detected to 6 ng/mL. TCE concentrations ranged from non-detected to 14 ng/mL. Toluene concentrations ranged from non-detected to <1 ng/mL. Xylene concentrations ranged from non-detected to trace. PCE and ethylbenzene were not detected in any sample location at this site. Unidentified late peaks ranged from at <10 ng/mL to <16 ng/mL (as benzene). External radio source interference prevented detection of target compounds below 10 ng/mL for each analyte, if any present, during the analysis of sample 035.

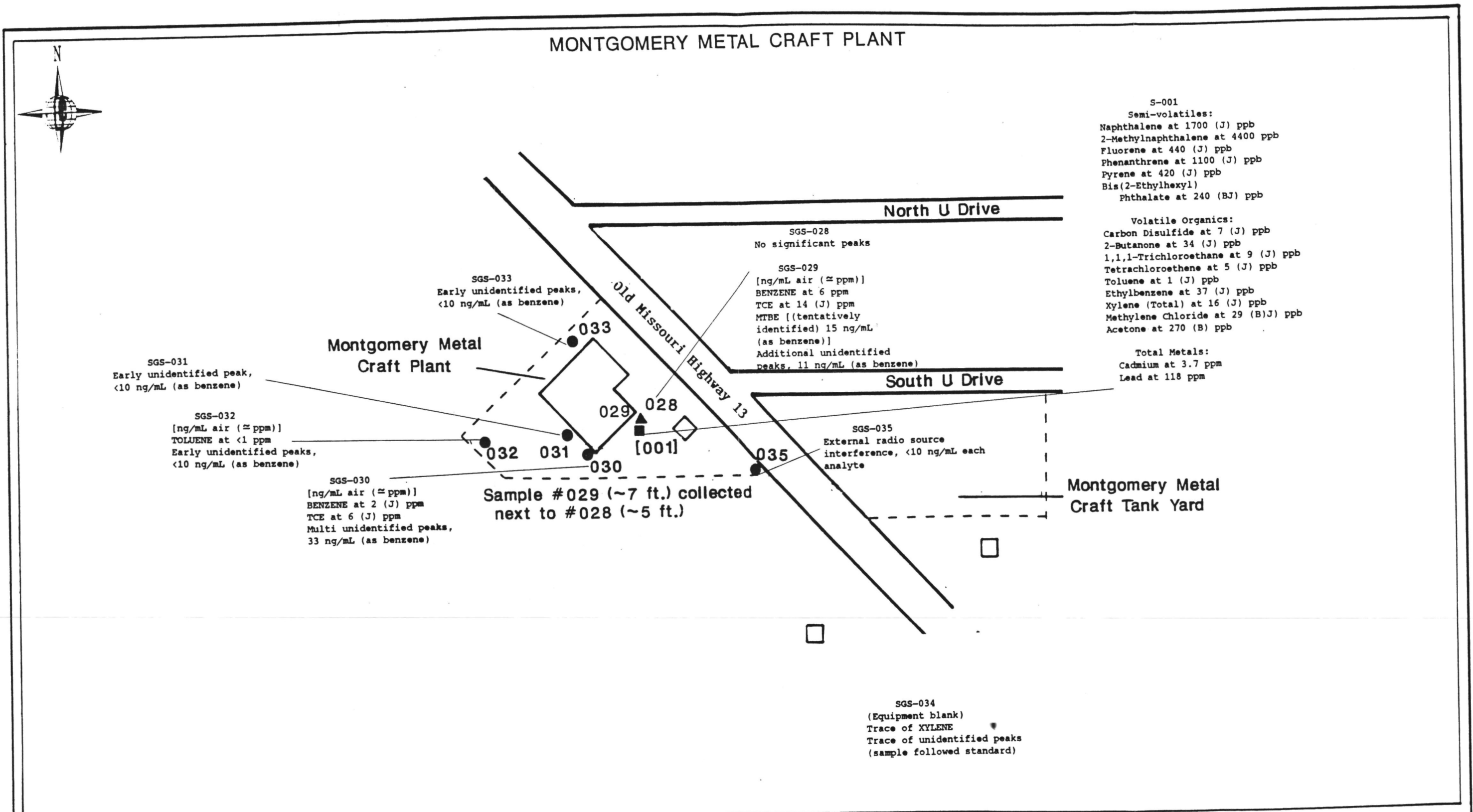
#### Coble Sinkhole

The soil-gas investigation produced five soil-gas samples at the Coble sinkhole (Figures 2.3-1 and 4.1-5). Soil-gas results are summarized in Table 4.1-5. Sample numbers were from 036 through 040. No field equipment blank sample was collected at this location.

External radio source interference prevented detection of target compounds below 10 ng/mL for each analyte, if any present, during the analysis of all samples at this site location.

#### Degraffenreid Sinkhole

The soil-gas investigation produced six soil-gas samples at the Montgomery Metal Craft plant (Figures 2.3-1 and 4.1-6). Soil-gas results are summarized in Table 4.1-6. Sample numbers were from 041 through 046. No field equipment or ambient air blank samples were collected at this site location.



**SOIL-GAS SAMPLE SERIES MG2016-SG-**  
 001: Soil-Gas Sample Number  
 ● : Shallow Soil-Gas Sample (~5 feet)  
 ○ : Deep Soil-Gas Sample (~10 feet)  
 ▲ : Shallow and Deep Soil-Gas Samples

**SOIL SAMPLE SERIES MG2014-S-**  
 [001]: Soil Sample Number  
 □ : Residence or Other Structure  
 ■ : Soil Sample (~5 feet)

Scale 1 inch = 201.59 feet  
 0 200' 400'

PROJECT NUMBER: MG2018

ecology and environment, inc.  
 OVERLAND PARK, KANSAS

**NORTH U DRIVE SITE**

Prepared by: OS  
 Revised by: TMF

Date: 1/21/91  
 Date: 2/04/91

Figure 4.1-4: Soil-Gas and Soil Sampling Results

TABLE 4.1-4

SOIL-GAS DATA FOR NORTH U DRIVE  
MONTGOMERY METAL CRAFT PLANT  
SPRINGFIELD, GREENE COUNTY, MISSOURI  
ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
SERIES MG2016-SGS  
(CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL-BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-028	10/15/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-029	10/15/90	1	6	14	N.D.	N.D.	N.D.	N.D.	MTBE (tentatively identified) 15 ng/mL (as benzene) additional unidentified peaks, 11 ng/mL (as benzene)
SGS-030	10/15/90	1	2(J)	6(J)	N.D.	N.D.	N.D.	N.D.	Multi unidentified peaks, 33 ng/mL (as benzene) (Holding time exceeded by 15 minutes)
SGS-031	10/15/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak, <10 ng/mL (as benzene)
SGS-032	10/15/90	1	N.D.	N.D.	<1	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-033	10/15/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-034	10/15/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	Trace	Trace unidentified peaks (sample followed standard) (Equipment blank)
SGS-035	10/15/90		*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte

Notes: See Figures 2.3-1 and 4.1-4 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

The J flag indicates an estimated value. This could refer to a value for a compound which did not exhibit linear detector response (TCE, PCE), or it could represent a sample analysis which exceeded the specified one-hour holding time.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

\* = External radio source interference

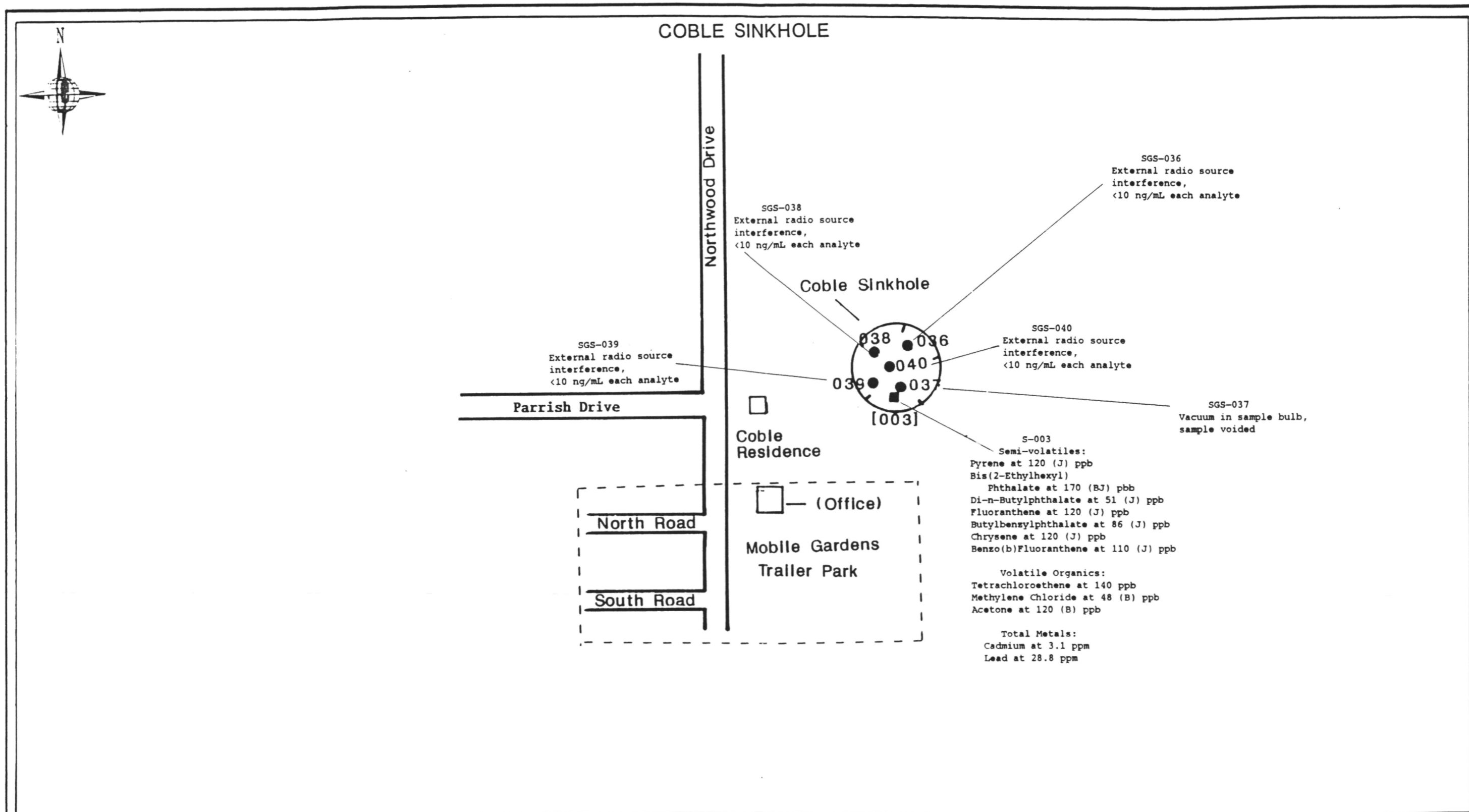


TABLE 4.1-5

SOIL-GAS DATA FOR NORTH U DRIVE  
COBLE SINKHOLE  
SPRINGFIELD, GREENE COUNTY, MISSOURI  
ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
SERIES MG2016-SGS  
(CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL- BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-036	10/15/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte
SGS-037	10/15/90	10	*	*	*	*	*	*	Vacuum in sample bulb, sample voided
SGS-038	10/15/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte
SGS-039	10/15/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte
SGS-040	10/15/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte

Notes: See Figures 2.3-1 and 4.1-5 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

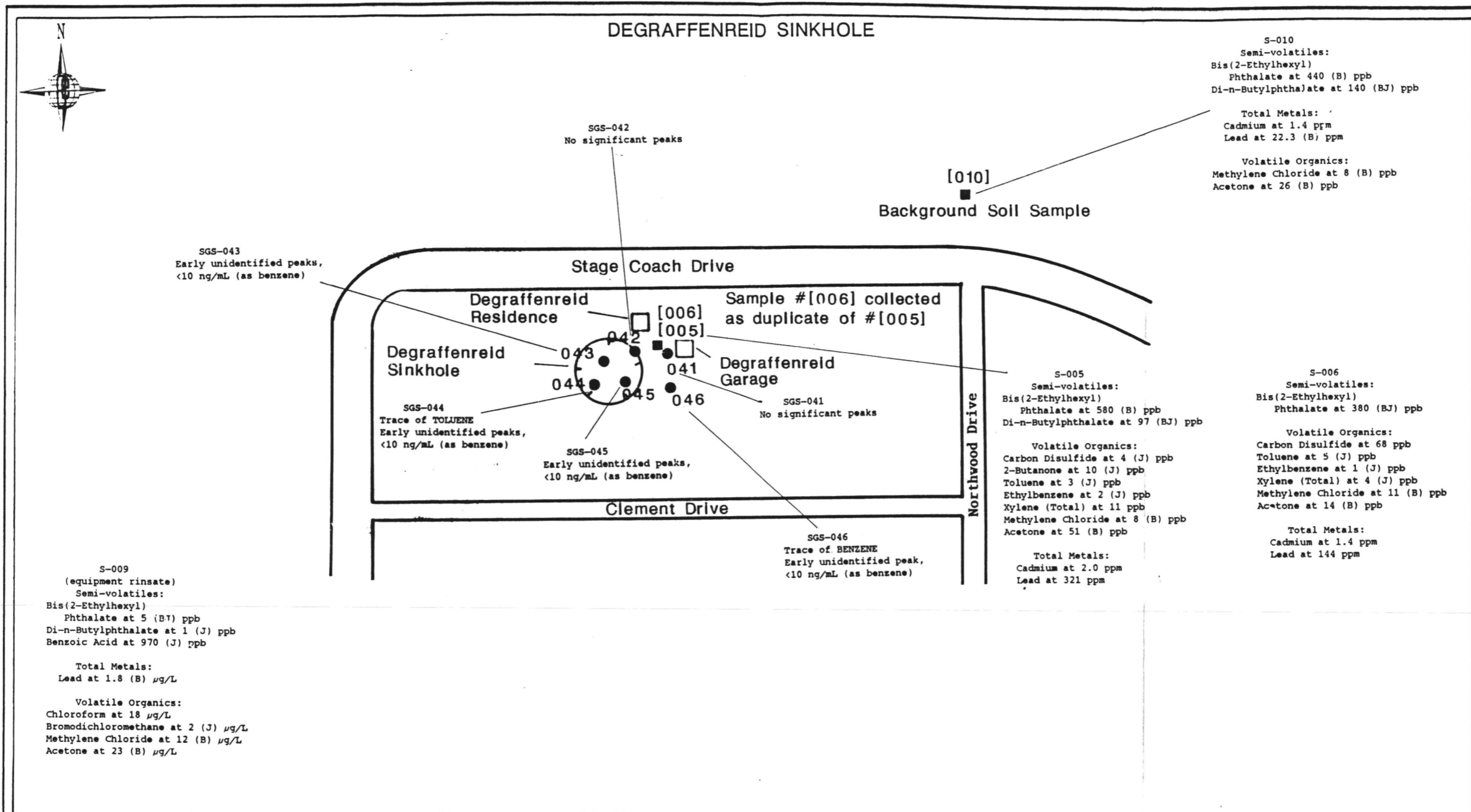
The J flag indicates an estimated value. This could refer to a value for a compound which did not exhibit linear detector response (TCE, PCE), or it could represent a sample analysis which exceeded the specified one-hour holding time.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

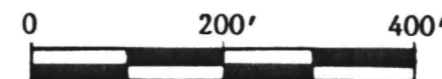
\* = External radio source interference.



**SOIL-GAS SAMPLE SERIES MG2016-SG-**  
**001:** Soil-Gas Sample Number  
 ● : Shallow Soil-Gas Sample (~5 feet)  
 ○ : Deep Soil-Gas Sample (~10 feet)  
 ▲ : Shallow and Deep Soil-Gas Samples

**SOIL SAMPLE SERIES MG2014-S-**  
**[001]:** Soil Sample Number  
 □ : Residence or Other Structure  
 ■ : Soil Sample (~5 feet)

Scale 1 inch = 201.59 feet



PROJECT NUMBER: MG2018

TABLE 4.1-6

SOIL-GAS DATA FOR NORTH U DRIVE  
DEGRAFFENREID SINKHOLE  
SPRINGFIELD, GREENE COUNTY, MISSOURI  
ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
SERIES MG2016-SGS  
(CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL- BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-041	10/16/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-042	10/16/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-043	10/16/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-044	10/16/90	1	N.D.	N.D.	Trace	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-045	10/16/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-046	10/16/90	1	Trace	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak, <10 ng/mL (as benzene)

Notes: See Figures 2.3-1 and 4.1-6 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

Benzene and toluene concentrations ranged from non-detected to trace. Xylene, TCE, PCE and ethylbenzene were not detected in any sample location at this site. Early unidentified peaks at <10 ng/mL to <16 ng/mL (as benzene) were detected in four sample locations.

#### Parrish Drive and Stage Coach Drive

The soil-gas investigation produced nine soil-gas samples along the Parrish Drive and Stage Coach Drive (Figures 2.3-1 and 4.1-7). Soil-gas results are summarized in Table 4.1-7. Sample numbers were from 047 through 049, and from 079 through 084. One field equipment (080) and two ambient air (048 and 081) blank samples were collected for QA/QC.

Only three early unidentified peaks at <10 ng/mL (as benzene) were detected at these sample locations, all other sample results were non-detected.

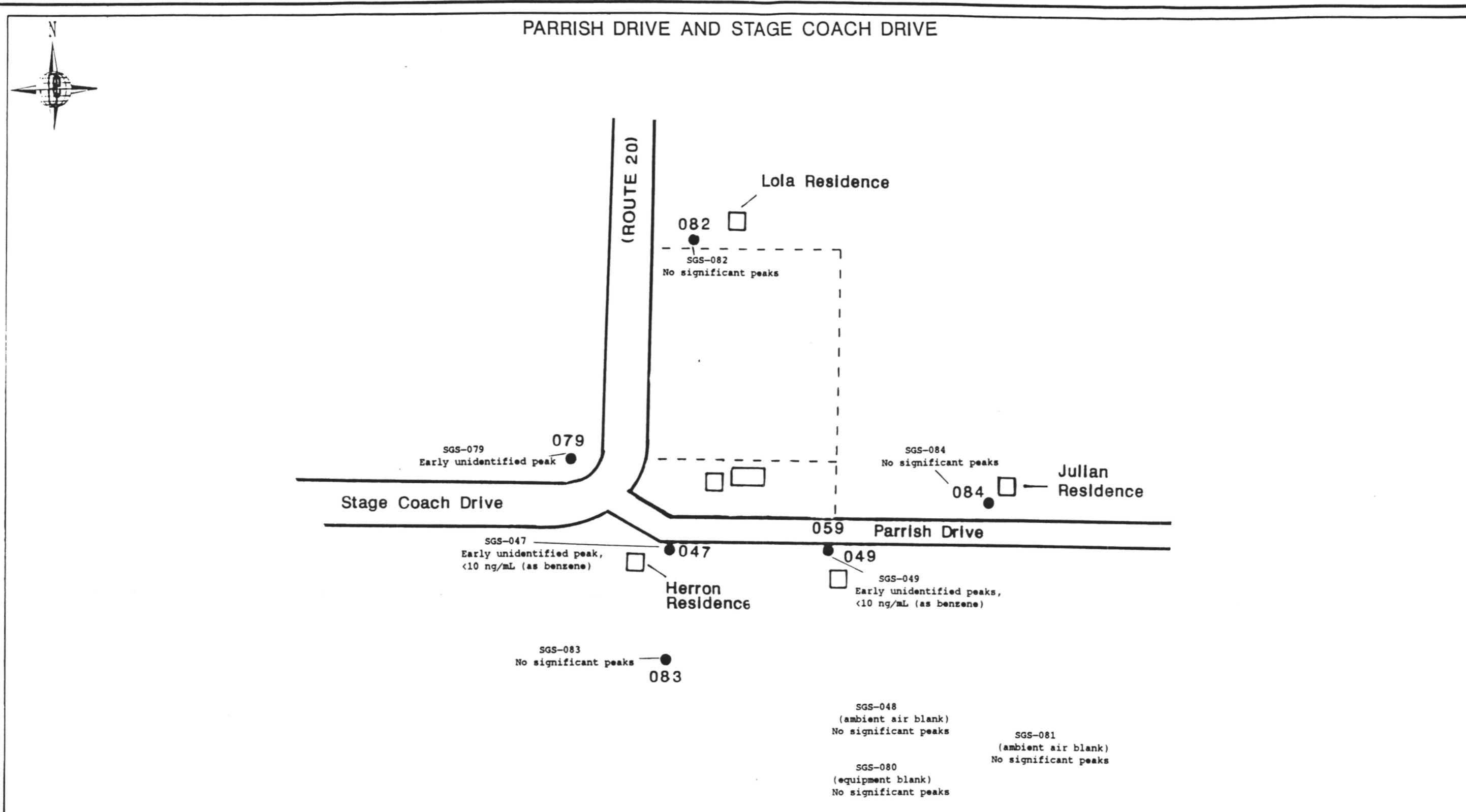
#### Frazier Brothers Construction Company

The soil-gas investigation produced ten soil-gas samples at the Frazier Brothers Construction Company (Figures 2.3-1 and 4.1-8). Soil-gas results are summarized in Table 4.1-8. Sample numbers were from 050 through 059. No field equipment or ambient air blank samples were collected at this location.

Benzene concentrations ranged from non-detected to <1 ng/mL. Toluene concentrations ranged from non-detected to trace. TCE concentrations ranged from non-detected to 1 (J) ng/mL. Xylene, PCE and ethylbenzene were not detected in any sample location at this site. Early unidentified peaks at <10 ng/mL (as benzene) were detected in six sample locations. Multi unidentified peaks at <10 ng/mL (as benzene) were detected in two sample locations.

#### Former Curtis Service Station

The soil-gas investigation produced 14 soil-gas samples at the Former Curtis Service Station (Figures 2.3-1 and 4.1-9). Soil-gas results are summarized in Table 4.1-9. Sample numbers were from 060



**SOIL-GAS SAMPLE SERIES MG2016-SG-**  
 001: Soil-Gas Sample Number  
 ● : Shallow Soil-Gas Sample (~5 feet)  
 ○ : Deep Soil-Gas Sample (~10 feet)  
 ▲ : Shallow and Deep Soil-Gas Samples

**SOIL SAMPLE SERIES MG2014-S-**  
 [001]: Soil Sample Number  
 □ : Residence or Other Structure  
 ■ : Soil Sample (~5 feet)

Scale 1 inch = 201.59 feet



PROJECT NUMBER: MG2018

TABLE 4.1-7

SOIL-GAS DATA FOR NORTH U DRIVE  
 ALONG PARRISH DRIVE AND STAGE COACH DRIVE  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SERIES MG2016-SGS  
 (CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL-BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-047	10/16/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak, <10 ng/mL (as benzene) (1)
SGS-048	10/16/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (holding time exceeded by 10 minutes) (ambient air blank) (1)
SGS-049	10/16/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-079	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak (2)
SGS-080	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (equipment blank) (2)
SGS-081	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (ambient air blank) (2)
SGS-082	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (3)
SGS-083	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (4)
SGS-084	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks (5)

Notes: See Figure 2.3-1 and 4.1-7 for sampling locations.

- (1) Along Parrish Drive
- (2) At the northwestern corner of the intersection of Parrish and Stage Coach Drive
- (3) Along Stage Coach Drive (Lola's residence)
- (4) At the backyard of Herron's residence
- (5) At the frontyard of Julian's residence

The soil-gas survey was designed to provide Level II data quality.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

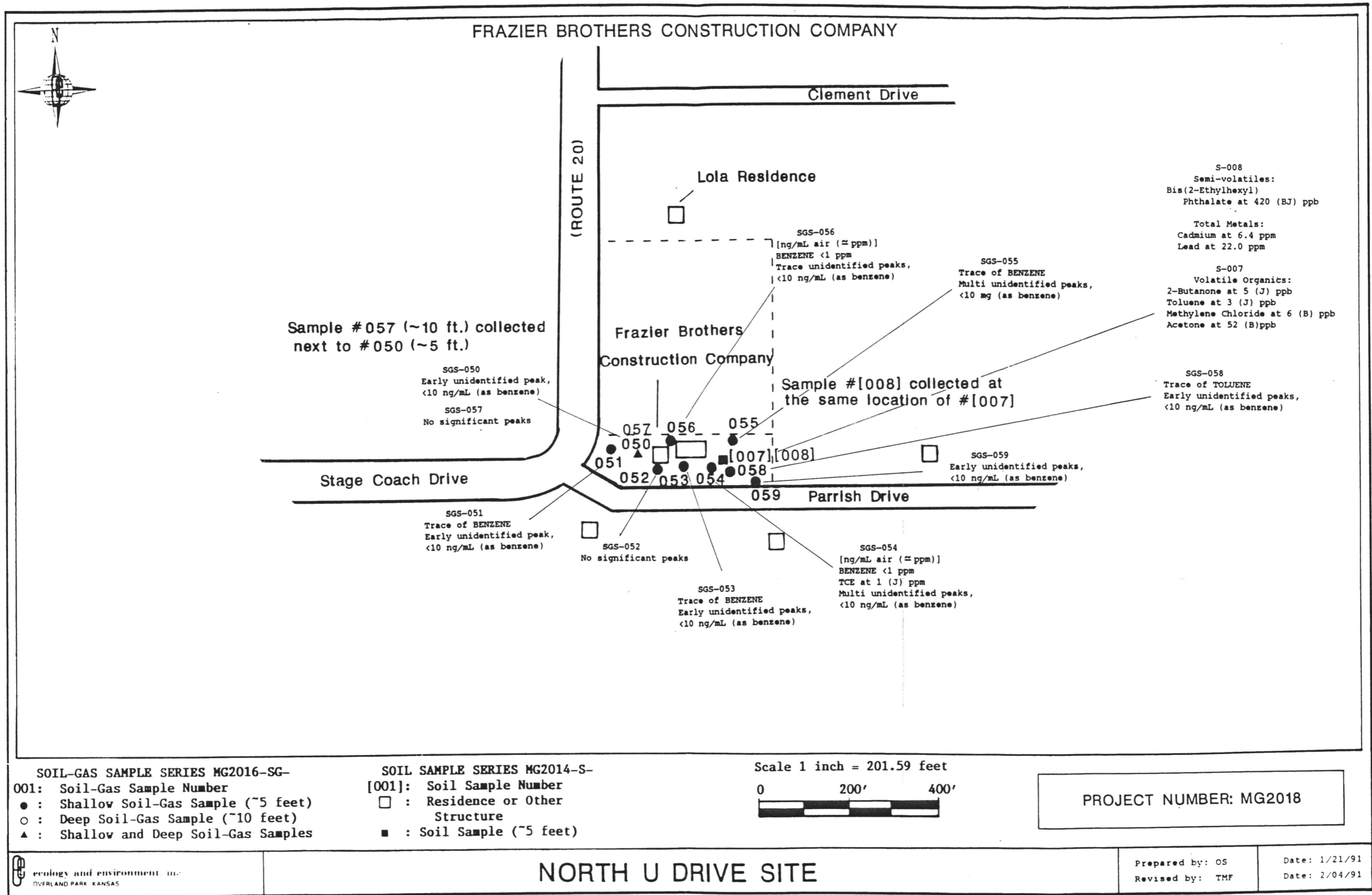


Figure 4.1-8: Soil-Gas and Soil Sampling Results

TABLE 4.1-8

SOIL-GAS DATA FOR NORTH U DRIVE  
 FRAZIER BROTHERS CONSTRUCTION COMPANY  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SERIES MG2016-SGS  
 (CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL-BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-050	10/17/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak, <10 ng/mL (as benzene)
SGS-051	10/17/90	1	Trace	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak, <10 ng/mL (as benzene)
SGS-052	10/17/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-053	10/17/90	1	Trace	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-054	10/17/90	1	<1	1(J)	N.D.	N.D.	N.D.	N.D.	Multi unidentified peaks, <10 ng/mL (as benzene)
SGS-055	10/17/90	1	Trace	N.D.	N.D.	N.D.	N.D.	N.D.	Multi unidentified peaks, <10 ng (as benzene)
SGS-056	10/17/90	1	<1	N.D.	N.D.	N.D.	N.D.	N.D.	Trace unidentified peaks, <10 ng/mL (as benzene)
SGS-057	10/17/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	No significant peaks
SGS-058	10/17/90	1	N.D.	N.D.	Trace	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-059	10/18/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)

Notes: See Figures 2.3-1 and 4.1-8 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

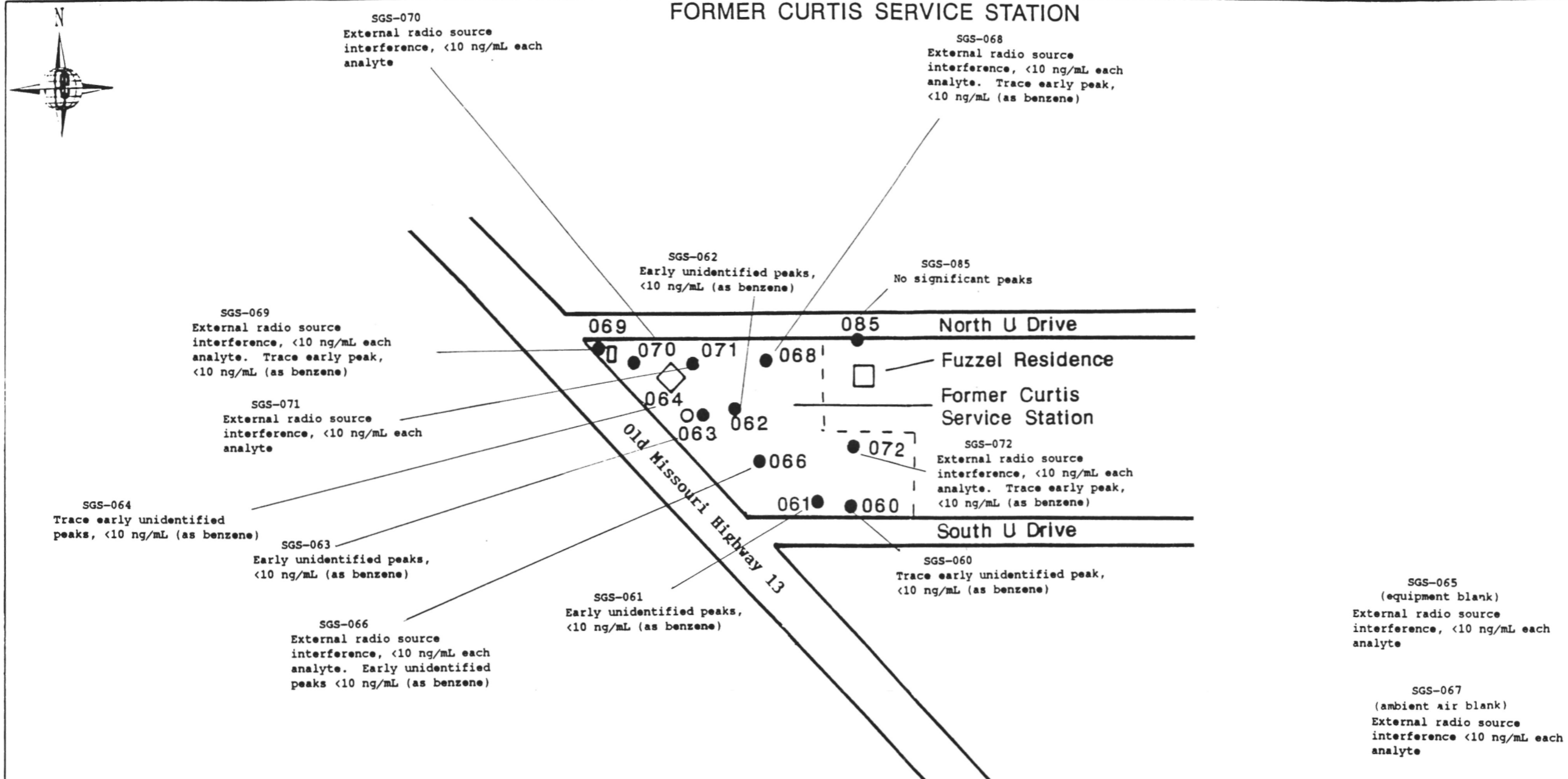
The J flag indicates an estimated value. This could refer to a value for a compound which did not exhibit linear detector response (TCE, PCE), or it could represent a sample analysis which exceeded the specified one-hour holding time.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

# FORMER CURTIS SERVICE STATION



## SOIL-GAS SAMPLE SERIES MG2016-SG-

001: Soil-Gas Sample Number

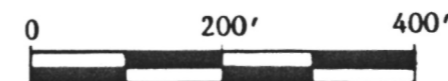
- : Shallow Soil-Gas Sample (~5 feet)
- : Deep Soil-Gas Sample (~10 feet)
- ▲ : Shallow and Deep Soil-Gas Samples

## SOIL SAMPLE SERIES MG2014-S-

[001]: Soil Sample Number

- : Residence or Other Structure
- : Soil Sample (~5 feet)

Scale 1 inch = 201.59 feet



PROJECT NUMBER: MG2018

TABLE 4.1-9

SOIL-GAS DATA FOR NORTH U DRIVE  
FORMER CURTIS SERVICE STATION  
SPRINGFIELD, GREENE COUNTY, MISSOURI  
ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
SERIES MG2016-SGS  
(CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL-BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-060	10/18/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Trace early unidentified peak, <10 ng/mL (as benzene)
SGS-061	10/18/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-062	10/18/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-063	10/18/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peaks, <10 ng/mL (as benzene)
SGS-064	10/18/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Trace early unidentified peaks, <10 ng/mL (as benzene)
SGS-065	10/18/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte (Equipment Blank)
SGS-066	10/18/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte; Early unidentified peaks <10 ng/mL (as benzene)
SGS-067	10/18/90	10	*	*	*	*	*	*	External radio source interference <10 ng/mL each analyte (Ambient Air Blank)
SGS-068	10/18/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte. Trace early peak?, <10 ng/mL (as benzene)
SGS-069	10/18/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte. Trace early peak, <10 ng/mL (as benzene)
SGS-070	10/18/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte
SGS-071	10/18/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte
SGS-072	10/18/90	10	*	*	*	*	*	*	External radio source interference, <10 ng/mL each analyte. Trace early peak, <10 ng/mL (as benzene)
SGS-085	10/19/90	10	*	*	*	*	*	*	No significant peaks

Notes: See Figures 2.3-1 and 4.1-9 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

\*: External radio interference prevented detection of target compounds below 10 ng/mL for each analyte.

through 072, and sample 085. No field equipment or ambient air blank samples were collected at this location.

Early unidentified peaks at <10 ng/mL (as benzene) were detected in 5 sample locations (060 through 064). External radio source interference prevented detection of target compounds below 10 ng/mL for each analyte, if any present, during the analysis of 9 samples (065 through 072, and sample 085) at this site location.

#### Former Derby Service Station

The soil-gas investigation produced six soil-gas samples at the Former Derby Service Station (Figures 2.3-1 and 4.1-10). Soil-gas results are summarized in Table 4.1-10. Sample numbers were from 073 through 078. No field equipment or ambient air blank samples were collected at this location.

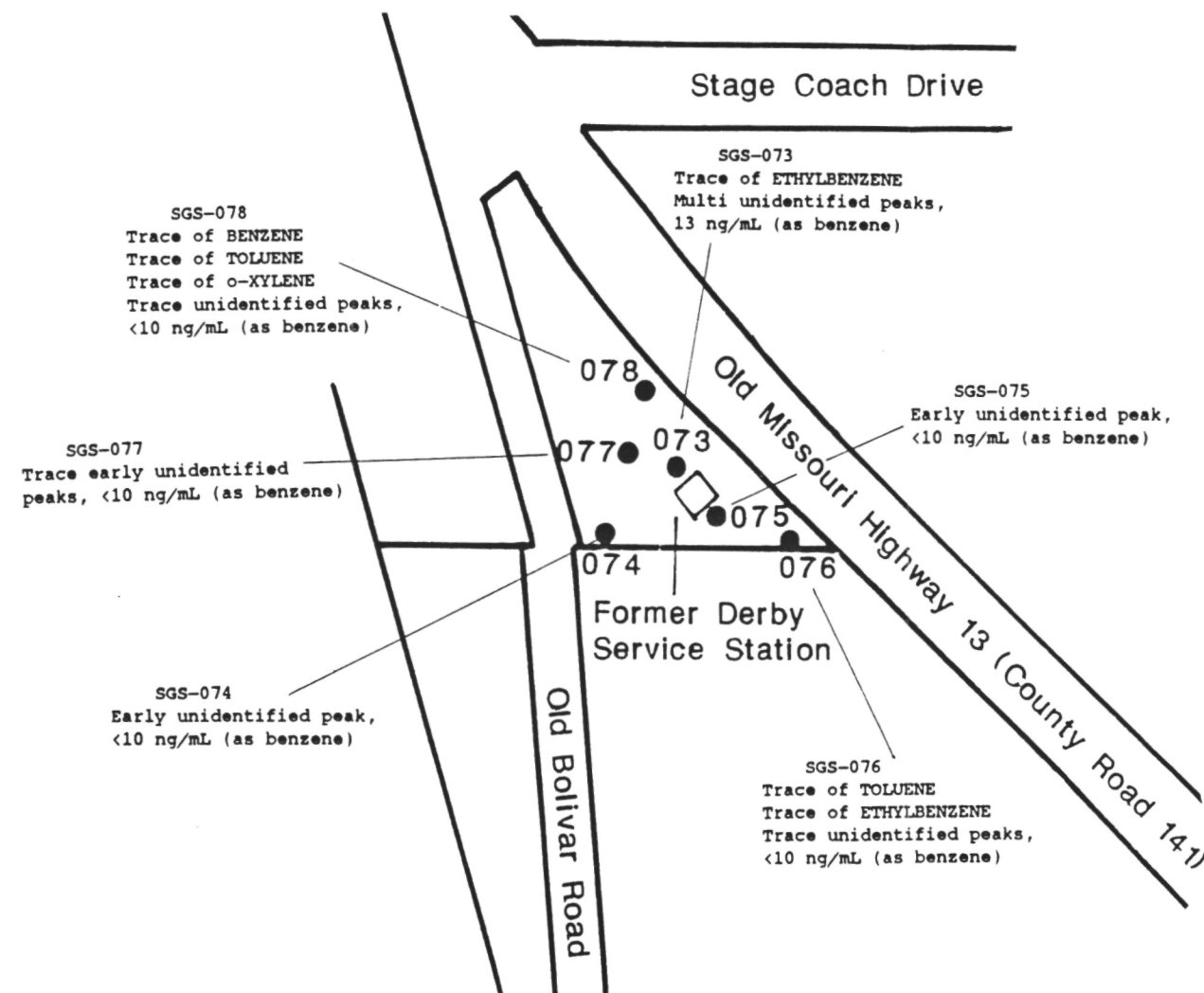
Benzene, toluene, xylene and ethylbenzene concentrations ranged from non-detected to trace. TCE and PCE were not detected in any sample location at this site. Early unidentified peaks at <10 ng/mL (as benzene) were detected in 5 sample locations. Multi unidentified peaks at <13 ng/mL (as benzene) was detected in one sample locations.

#### 4.1.3 Soil Sample Results

The samples were submitted for low detection limit analysis. Units for inorganic compounds (total metals) data are presented in milligrams per kilogram, (mg/kg). All other results are presented in micrograms per kilogram, (µg/kg), except for the QA/QC equipment rinsate sample #009. The results for this sample are presented in micrograms per liter, (µg/L). Sample #006 was collected as a duplicate sample of #005.

As before, concentrations that are qualified "J" indicate an estimated value. This code is used either when estimating a concentration for tentatively identified compounds where a 1:1 gas chromatograph detector response is assumed, or when the mass spectral data indicates the presence of a compound that meets the identification criteria but the result is less than the sample quantitation limit but greater than zero.

# FORMER DERBY SERVICE STATION



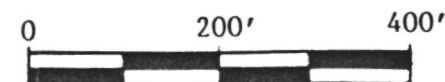
## SOIL-GAS SAMPLE SERIES MG2016-SG-

- 001: Soil-Gas Sample Number
- : Shallow Soil-Gas Sample (~5 feet)
  - : Deep Soil-Gas Sample (~10 feet)
  - ▲ : Shallow and Deep Soil-Gas Samples

## SOIL SAMPLE SERIES MG2014-S-

- [001]: Soil Sample Number
- : Residence or Other Structure
  - : Soil Sample (~5 feet)

Scale 1 inch = 201.59 feet



PROJECT NUMBER: MG2018

TABLE 4.1-10

SOIL-GAS DATA FOR NORTH U DRIVE  
FORMER DERBY SERVICE STATION  
SPRINGFIELD, GREENE COUNTY, MISSOURI  
ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
SERIES MG2016-SGS  
(CONCENTRATIONS IN ng/mL AIR [ $\approx$  ppm])

SAMPLE NUMBER	DATE OF COLLECTION	DETECTION LIMIT (ppm)	BENZENE	TCE	TOLUENE	PCE	ETHYL- BENZENE	XYLENE	COMMENTS <sup>(1)</sup>
SGS-073	10/19/90	1	N.D.	N.D.	N.D.	N.D.	Trace	N.D.	Multi unidentified peaks, 13 ng/mL (as benzene)
SGS-074	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak, <10 ng/mL (as benzene)
SGS-075	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Early unidentified peak, <10 ng/mL (as benzene)
SGS-076	10/19/90	1	N.D.	N.D.	Trace	N.D.	Trace	N.D.	Trace unidentified peaks, <10 ng/mL (as benzene)
SGS-077	10/19/90	1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Trace early unidentified peaks, <10 ng/mL (as benzene)
SGS-078	10/19/90	1	Trace	N.D.	Trace	N.D.	N.D.	Trace	Trace unidentified peaks, <10 ng/mL (as benzene)

Notes: See Figure 2.3-1 and 4.1-10 for sampling locations.

Notes: See Figures 2.3-1 and 4.1-2 for sampling locations.

The soil-gas survey was designed to provide Level II data quality.

Trace indicates possible detection below one nanogram per milliliter (ng/mL) air [ $\approx$  ppm]. Less than 1 ng/mL (<1 ng/mL) indicates probable detection at an unreliable quantitation limit.

- (1) An unidentified peak or peaks is self-explanatory. An early peak indicates an unidentified compound which is more volatile than benzene; the compound could be halogenated, such as methylene chloride, or an aliphatic hydrocarbon like hexane. A late peak designation indicates an unidentified compound having volatility and/or structure similar to the later-eluting targets (PCE, xylene).

N.D.: Non-detect, no compounds were detected above the detection limit.

The "B" qualifier code was used when the analyte was found in the associated QA/QC blank as well as in the sample. Background soil sample results for volatile organics parameters were non-detected, except for methylene chloride and acetone, 8 (B)  $\mu\text{g/kg}$  and 26 (B)  $\mu\text{g/kg}$ , respectively. Background soil sample results for semi-volatile organics parameters were non-detected, except for bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and benzoic acid, 440 (B)  $\mu\text{g/kg}$ , 140 (BJ)  $\mu\text{g/kg}$  and 970 (J)  $\mu\text{g/kg}$ , respectively. Phthalate compounds are common laboratory contaminants and are commonly used as a plasticizing additive. Background soil sample results for total cadmium and lead parameters were 1.4  $\mu\text{g/kg}$  and 22.3 (B), respectively.

#### Montgomery Metal Craft Plant

One soil sample [001] was obtained at the Montgomery Metal Craft Plant (Figures 2.3-1 and 4.1-4). Sample results for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic compounds, in Table 4.1-13. No compounds in the analysis of pesticide organics were detected.

The volatile organic analysis identified carbon disulfide at 7 (J)  $\mu\text{g/kg}$ , 2-butanone at 34 (J)  $\mu\text{g/kg}$ , 1,1,1-trichloroethane (TCA) at 9 (J)  $\mu\text{g/kg}$ , tetrachloroethene (PCE) at 5 (J)  $\mu\text{g/kg}$ , toluene at 1 (J)  $\mu\text{g/kg}$ , ethylbenzene at 37 (J)  $\mu\text{g/kg}$ , total xylene at 16 (J)  $\mu\text{g/kg}$ , and methylene chloride at 29 (BJ)  $\mu\text{g/kg}$ , acetone at 270 (B)  $\mu\text{g/kg}$ .

Methylene chloride and acetone are common laboratory contaminants. These compounds were also found in the associated blank, and is most likely attributed to laboratory contamination. These two compounds . The Montgomery Metal Craft Plant used to clean tanks containing compounds associated with petroleum products (such as toluene, ethylbenzene and xylene) in the vicinity of this sample location which may explain the detection of these compounds in the soil. Carbon disulfide is used in the manufacture of paint removers, varnishes, varnish removers, and also used as degreaser, which may have been utilized at this location during the restoration of tanks. Tetrachloroethene (perchloroethylene

TABLE 4.1-11

SOIL SAMPLE ANALYSIS SUMMARY FOR NORTH U DRIVE  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SAMPLE SERIES MG2014-S  
 VOLATILE ORGANIC COMPOUNDS/LOW DETECTION LIMIT  
 (CONCENTRATIONS AS MICROGRAMS PER KILOGRAM,  $\mu\text{g}/\text{kg}$  [ppb], UNLESS NOTED)

PARAMETERS	SAMPLE NUMBER									
	001	002	003	004	005	006	007	008	009	010
	SAMPLE LOCATIONS									
	MONTGOMERY'S PLANT	MONTGOMERY'S TANK YARD	COBLE'S SINKHOLE	MOBILE GARDEN'S SINKHOLE	DEGRAFFENREID SINKHOLE	DEGRAFFENREID SINKHOLE	FRAZIER BROTHERS	N/A	(RINSATE)	STAGECOACH AND NORTHWOOD DRIVE
Carbon disulfide	7(J)	<25	<24	<6	4(J)	68	<5	-	<5	<5
Chloroform	<30	<25	<24	3(BJ)	<7	<6	<5	-	18 $\mu\text{g}/\text{L}$	<5
2-Butanone	34(J)	<49	<48	<12	10(J)	<12	5(J)	-	<10	<10
1,1,1-Trichloroethane	9(J)	<25	<24	<6	<7	<6	<5	-	<5	<5
Bromodichloromethane	<30	<25	<24	<6	<7	<6	<5	-	2(J) $\mu\text{g}/\text{L}$	<5
Tetrachloroethene	5(J)	34	140	<6	<7	<6	<5	-	<5	<5
Toluene	1(J)	<25	<24	<6	3(J)	5(J)	3(J)	-	<5	<5
Ethylbenzene	37(J)	<25	<24	<6	2 J)	1(J)	<5	-	<5	<5
Xylene (Total)	16(J)	10(J)	<24	<6	11	4(J)	<5	-	<5	<5
Methylene Chloride	29(BJ)	27(B)	48(B)	16(B)	8(B)	11(B)	6(B)	-	12(B) $\mu\text{g}/\text{L}$	8(B)
Acetone	270(B)	160(B)	120(B)	23(B)	51(B)	14(B)	52(B)	-	23(B) $\mu\text{g}/\text{L}$	26(B)

Notes: Soil sample results are preliminary data provided by the E & E Analytical Services Center Laboratory. This Contract Laboratory Program (CLP) data is subject to validation by the Missouri Department of Natural Resources (MDNR). See Figure 2.3-1 for sample locations.

The samples were submitted for low detection limit analysis. Units for volatile organics compounds data are presented in micrograms per kilogram,  $\mu\text{g}/\text{kg}$  (ppb), except for sample #009 [an equipment rinsate (water sample) for QA/QC purposes] for which all results are presented in micrograms per liter,  $\mu\text{g}/\text{L}$  (ppb). Sample #006 was collected as duplicate sample of #005. Sample #010 was collected as a background sample. Sample #008 was collected for non-volatile compounds analysis.

<25": Less than detection limit (25  $\mu\text{g}/\text{kg}$ ).

N.D.: None Detected.

(J): Indicates an estimated value. This code is used either when estimating a concentration for tentatively identified compounds where a 1:1 response is assumed, or when the mass spectral data indicates the presence of a compound that meets the identification criteria but the result is less than the sample quantitation limit but greater than zero.

(B): This code is used when the analyte is found in the associated blank as well as in the sample.

TABLE 4.1-12

SOIL SAMPLE ANALYSIS SUMMARY ON NORTH U DRIVE  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SAMPLE SERIES M32014-S  
 SEMI-VOLATILE ORGANIC COMPOUNDS/LOW DETECTION LIMIT  
 (CONCENTRATIONS AS MICROGRAMS PER KILOGRAM,  $\mu\text{g}/\text{kg}$  [ppb] UNLESS NOTED)

PARAMETERS	SAMPLE NUMBER									
	001	002	003	004	005	006	007	008	009	010
	SAMPLE LOCATIONS									
	MONTGOMERY'S PLANT	MONTGOMERY'S TANK YARD	COBLE'S SINKHOLE	MOBILE GARDEN'S SINKHOLE	DEGRAFFENREID SINKHOLE	DEGRAFFENREID SINKHOLE	N/A	FRAZIER BROTHERS	(RINSATE)	STAGECOACH AND NORTHWOOD DRIVE
Naphthalene	1700(J)	840	<410	<410	<450	<420	-	<430	<10	<390
2-Methylnaphthalene	4400	1500	<410	<410	<450	<420	-	<430	<10	<390
Fluorene	440	<390	<410	<410	<450	<420	-	<430	<10	<390
Phenanthrene	1100(J)	<390	<410	62(J)	<450	<420	-	<430	<10	<390
Pyrene	420(J)	<390	120(J)	200(J)	<450	<420	-	<430	<10	<390
Bis(2-Ethylhexyl) phthalate	240(BJ)	180(BJ)	170(BJ)	1000(B)	580(B)	380(BJ)	-	420(BJ)	5(BJ) $\mu\text{g}/\text{L}$	440(B)
Di-n-butylphthalate	<4000	<390	51(J)	<410	97(BJ)	<420	-	<430	1(J)	140(BJ)
Fluoranthene	<4000	<390	120(J)	200(J)	<450	<420	-	<430	<10	<390
Butylbenzylphthalate	<4000	<390	86(J)	82(J)	<450	<420	-	<430	<10	<390
Chrysene	<4000	<390	120(J)	100(J)	<450	<420	-	<430	<10	<390
Benzo(b)Fluoranthene	<4000	<390	110(J)	180(J)	<450	<420	-	<430	<10	<390
Benzo(a)Anthracene	<4000	<390	<410	94(J)	<450	<420	-	<430	<10	<390
Benzo(a)Pyrene	<4000	<390	<410	91(J)	<450	<420	-	<430	<10	<390
Indeno(1,2,3-cd)Pyrene	<4000	<390	<410	56(J)	<450	<420	-	<430	<10	<390
Benzoic Acid	<20,000	<1900	<2000	<2000	<2200	<2100	-	<2100	<50	970(J)

Notes: Soil sample results are preliminary data provided by the E & E Analytical Services Center Laboratory. This Contract Laboratory Program (CLP) data is subject to validation by the Missouri Department of Natural Resources (MDNR). See Figure 2.3-1 for sample locations.

The samples were submitted for low detection limit analysis. Units for semi volatiles data are presented in micrograms per kilogram,  $\mu\text{g}/\text{kg}$  (ppb), except for sample #009 (an equipment rinsate (water sample) for QA/QC purposes) for which all results are presented in micrograms per liter,  $\mu\text{g}/\text{L}$  (ppb). Sample #006 was collected as duplicate sample of #005. Sample #007 was collected only for MTBE and volatile organics analysis (VOAs). Sample #010 was collected as background.

"<410": Less than detection limit (410  $\mu\text{g}/\text{kg}$ ).

N.D.: None Detected.

J: Indicates an estimated value. This code is used either when estimating a concentration for tentatively identified compounds where a 1:1 response is assumed, or when the mass spectral data indicates the presence of a compound that meets the identification criteria but the result is less than the sample quantitation limit but greater than zero.

B: This code is used when the analyte is found in the associated blank as well as in the sample.

TABLE 4.1-13

SOIL SAMPLE ANALYSIS SUMMARY FOR NORTH U DRIVE  
 SPRINGFIELD, GREENE COUNTY, MISSOURI  
 ECOLOGY AND ENVIRONMENT, INC., OCTOBER 1990  
 SAMPLE SERIES MG2014-S  
 INORGANIC COMPOUNDS/LOW DETECTION LIMIT  
 (CONCENTRATIONS AS MILLIGRAMS PER KILOGRAM mg/kg [ppm] UNLESS NOTED)

PARAMETERS	SAMPLE NUMBER									
	001	002	003	004	005	006	007	008	009	010
	SAMPLE LOCATIONS									
	MONTGOMERY'S PLANT	MONTGOMERY'S TANK YARD	COBLE'S SINKHOLE	MOBIL GARDEN'S SINKHOLE	DEGRAFFENREID SINKHOLE	DEGRAFFENREID SINKHOLE	N/A	FRAXIER BROTHERS	(RINSATE)	STAGECOACH AND NORTHMOOD DRIVE
Cadmium	3.7	1.7	3.1	2.4	2.0	1.4	-	6.4	<5 µg/L	1.4
Lead	118	37.6	28.8	21.6	321	144	-	22.0	1.8(B)µg/L	22.3(B)

Notes: Soil sample results are preliminary data provided by the E & E Analytical Services Center Laboratory. This Contract Laboratory Program (CLP) data is subject to validation by the Missouri Department of Natural Resources (MDNR). See Figure 2.3-1 for sample locations.

The samples were submitted for low detection limit analysis. Units for total metals data are presented in milligrams per kilogram, mg/kg (ppm); all other results are presented in micrograms per kilogram, µg/kg (ppb), except for sample #009 [an equipment rinsate (water sample) for QA/QC purposes] for which all results are presented in micrograms per liter, µg/L (ppb). Sample #006 was collected as duplicate sample of #005. Sample #010 was collected as background. Sample #007 was collected only for MTBE and volatile organics analysis (VOA).

J: Indicates an estimated value. This code is used either when estimating a concentration for tentatively identified compounds where a 1:1 response is assumed, or when the mass spectral data indicates the presence of a compound that meets the identification criteria but the result is less than the sample quantitation limit but greater than zero.

B: This code is used when the analyte is found in the associated blank as well as in the sample.

"<5": Less than detection limit (5 µg/L).

or PCE), 2-butanone also known as methyl ethyl ketone or MEK and 1,1,1-trichloroethane (TCA) also are used as cleaning solvents, and may have been used during tank cleaning and/or were left in the tanks as residual from previous usage. Therefore, it is possible that spillage of such chemicals may have occurred at this site location. None of the above mentioned chemicals naturally occur in the soil.

Several tentatively identified volatile compounds also were detected at this sample, and are presented in Appendix C-1. These compounds are commonly related to petroleum products.

The semi-volatiles analysis detected naphthalene at 1700 (J)  $\mu\text{g/kg}$ , 2-methylnaphthalene at 4400  $\mu\text{g/kg}$ , fluorene at 440 (J)  $\mu\text{g/kg}$ , phenanthrene at 1100 (J)  $\mu\text{g/kg}$ , pyrene at 420 (J)  $\mu\text{g/kg}$ , bis(2-ethylhexyl)-phthalate at 240 (BJ)  $\mu\text{g/kg}$ . Naphthalene is used in the manufacture of lubricants and also produced from petroleum. The only reported use for 2-methylnaphthalene is in the syntheses of insecticides. Naphthalene and 2-methylnaphthalene do not naturally occur in soil. Fluorene, phenanthrene and pyrene are polycyclic aromatics hydrocarbons (PAHs) are formed under the geothermal conditions which lead to the formation of coal and petroleum. Natural environmental sources include volcanoes, forest fires, crude oil and oil shale.

Several tentatively identified semi-volatiles compounds also were detected at this sample, and are presented in Appendix C-1. These compounds are commonly related to solvents and/or petroleum products.

The inorganic (total metals) analysis identified cadmium at 3.7  $\mu\text{g/kg}$ , and lead at 118  $\mu\text{g/kg}$ . The cadmium concentration found at this sample location was within the observed range ( $<1$  to 11  $\mu\text{g/kg}$ ) for the background geochemistry of soils in Missouri. The lead concentration was above the Missouri soil range (10 to 70  $\mu\text{g/kg}$ , Connor and Shacklette 1975), and may be attributed to leaded petroleum products.

#### Montgomery Metal Craft Tank Yard

The soil investigation produced one soil sample [002] at the Montgomery Metal Craft Tank Yard (Figures 2.3-1 and 4.1-1). Sample results

for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic compounds, in Table 4.1-13. No compounds in the analysis of pesticide organics were detected.

The volatile organic analysis identified tetrachloroethene at 34 µg/kg, total xylene at 10 (J) µg/kg, methylene chloride at 27 (B) µg/kg, acetone at 160 (B) µg/kg.

Several tentatively identified volatile compounds also were detected at this sample, and are presented in Appendix C-1. These compounds are commonly related to solvents and/or petroleum products.

The semi-volatiles analysis detected naphthalene at 840 µg/kg, 2-methylnaphthalene at 1500 µg/kg, bis(2-ethylhexyl)phthalate at 180 (BJ) µg/kg. Naphthalene is used in the manufacture of lubricants and is also produced from petroleum. The only reported use for 2-methylnaphthalene is in the syntheses of insecticides. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant. These chemical compounds do not naturally occur in soil. The presence of non-natural compounds in the soils may be attributed to possible spills from contents of tanks stored at this yard.

Several tentatively identified semi-volatiles compounds also were detected at this sample, and are presented in Appendix C-1. These compounds are commonly related to petroleum products.

The inorganic (total metals) analysis identified cadmium at 1.7 µg/kg, lead at 37.6 µg/kg. Cadmium and lead concentrations found at this sample location were within the observed range for the background geochemistry of soils in Missouri, <1 to 11 µg/kg and 10 to 70 µg/kg, respectively (Connor and Shacklette 1975).

#### Coble Sinkhole

The soil investigation produced one soil sample [003] at the Coble Sinkhole (Figures 2.3-1 and 4.1-5). Sample results for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic

compounds, in Table 4.1-13. The pesticide organics analysis failed to substantiate the presence of any compounds.

The volatile organic analysis identified tetrachloroethene (perchloroethylene or PCE) at 140 µg/kg, methylene chloride at 48 (B) µg/kg, acetone at 120 (B) µg/kg. Methylene chloride and acetone are common laboratory contaminants. These compounds were also found in the associated blank and most likely attributed to laboratory contamination. The presence of PCE in the soil sample is not clear to date and will require further sampling to determine its origin. PCE is used as a cleaning solvent and does not naturally occur in the soil.

The semi-volatiles analysis detected pyrene at 120 (J) µg/kg, bis-(2-ethylhexyl)phthalate at 170 (BJ) µg/kg, di-n-butylphthalate at 51 (J) µg/kg, fluoranthene at 120 (J) µg/kg, butylbenzylphthalate at 86 (J) µg/kg, chrysene at 120 (J) µg/kg, benzo(b)fluoranthene at 110 (J) µg/kg. Pyrene, fluoranthene, chrysene, benzo(b)fluoranthene are polycyclic aromatics hydrocarbons (PAHs) are formed under the geothermal conditions which lead to the formation of coal and petroleum. Natural environmental sources include volcanoes, forest fires, crude oil and oil shale. Man-made sources include the thermal oxidation of pyrolysis of petroleum-derived substances. Bis(2-ethylhexyl)phthalate is commonly used as a plasticizing additive for polyvinyl chloride (PVC) resins. Di-n-butylphthalate is used in plasticizing vinyl acetate emulsion systems, and in cellulose esters. It is also used as an insect repellent. No information regarding use of butylbenzylphthalate could be obtained. Phthalate esters compounds are common laboratory contaminants.

Several tentatively identified semi-volatiles compounds also were detected at this sample, and are presented in Appendix C-1.

The inorganic (total metals) analysis identified cadmium at 3.1 µg/kg and lead at 28.8 µg/kg. Cadmium and lead concentrations found at this sample location were within the observed range for the background geochemistry of soils in Missouri, <1 to 11 µg/kg and 10 to 70 µg/kg, respectively (Connor and Shacklette 1975).

#### Mobile Gardens Trailer Park Sinkhole

The soil investigation produced one soil sample [004] at the Mobile Gardens Trailer Park Sinkhole (Figures 2.3-1 and 4.1-3). Sample results for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic compounds, in Table 4.1-13. No compounds in the analysis of pesticide organics were detected.

The volatile organic analysis identified chloroform at 3 (BJ)  $\mu\text{g/kg}$  methylene chloride at 16 (B)  $\mu\text{g/kg}$ , acetone at 23 (B)  $\mu\text{g/kg}$ . Methylene chloride, acetone, and chloroform are common laboratory contaminants. These compound were also found in the associated blank and most likely attributed to laboratory contamination.

The semi-volatiles analysis detected phenanthrene at 62 (J)  $\mu\text{g/kg}$ , pyrene at 200 (J)  $\mu\text{g/kg}$ , fluoranthene at 200 (J)  $\mu\text{g/kg}$ , butylbenzylphthalate at 82 (J)  $\mu\text{g/kg}$ , chrysene at 100 (J)  $\mu\text{g/kg}$ , benzo(b)fluoranthene at 180 (J)  $\mu\text{g/kg}$ , benzo(a)anthracene at 94 (J)  $\mu\text{g/kg}$ , benzo(a)pyrene at 91 (J)  $\mu\text{g/kg}$ , indeno(1,2,3-cd)pyrene at 56 (J)  $\mu\text{g/kg}$  and Bis(2-ethylhexyl)phthalate at 1,000 (b)  $\mu\text{g/kg}$ . Phenanthrene, pyrene, fluoranthene, chrysene, benzo(b)fluoranthene, benzo(a)anthracene, benzo(a)pyrene and indeno(1,2,3-cd)pyrene are polycyclic aromatics hydrocarbons (PAHs) are formed under the geothermal conditions which lead to the formation of coal and petroleum. Natural environmental sources include volcanoes, forest fires, crude oil and oil shale.

No information regarding use of butylbenzylphthalate could be obtained; however, phthalates (including Bis(2-ethylhexyl)phthalate) are common laboratory contaminants.

Several tentatively identified semi-volatiles compounds also were detected at this sample, and are presented in Appendix C-1. These compounds are commonly related to petroleum products.

The inorganic (total metals) analysis identified cadmium at 2.4  $\mu\text{g/kg}$  and lead at 21.6  $\mu\text{g/kg}$ . Cadmium and lead concentrations found at this sample location were within the observed range for the background geochemistry of soils in Missouri, <1 to 11  $\mu\text{g/kg}$  and 10 to 70  $\mu\text{g/kg}$ , respectively (Connor and Shacklette 1975).

### Degraffenreid Sinkhole

The soil investigation produced two soil samples [005 and 006] at the Degraffenreid Sinkhole (Figures 2.3-1 and 4.1-6). Sample [006] was collected as duplicate of sample [005]. Sample results for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic compounds, in Table 4.1-13. No compounds in the analysis of pesticide organics were detected.

The volatile organic analysis of sample [005] identified carbon disulfide at 4 (J)  $\mu\text{g/kg}$ , 2-butanone (MEK) at 10 (J)  $\mu\text{g/kg}$ , toluene at 3 (J)  $\mu\text{g/kg}$ , ethylbenzene at 2 (J)  $\mu\text{g/kg}$ , total xylene at 11  $\mu\text{g/kg}$ , methylene chloride at 8 (B)  $\mu\text{g/kg}$ , and acetone at 51 (B)  $\mu\text{g/kg}$ . The volatile organics analysis of sample [006] detected carbon disulfide at 68  $\mu\text{g/kg}$ , toluene at 5 (J)  $\mu\text{g/kg}$ , ethylbenzene at 1 (J)  $\mu\text{g/kg}$ , total xylene at 4 (J)  $\mu\text{g/kg}$ , methylene chloride at 11 (B)  $\mu\text{g/kg}$ , and acetone at 14 (B)  $\mu\text{g/kg}$ . Methylene chloride and acetone are common laboratory contaminants. These compounds were also found in the associated blank and most likely attributed to laboratory contamination.

The Degraffenreid garage is utilized as a body shop for automobile and agricultural equipment repair near the vicinity of this sample location which may explain the detection of solvent compounds in the soil. Carbon disulfide is used in the manufacture of paint removers, varnishes, varnish removers, and also used as degreaser. It may have been utilized at this location for parts and or tools cleaning. Tetrachloroethene (perchloroethylene or PCE), 2-butanone (methyl ethyl ketone or MEK) and 1,1,1-trichloroethane (TCA) also are used as cleaning solvents, and also may have been used during parts and/or tools cleaning. Toluene, ethylbenzene and xylene are solvents and compounds encountered in petroleum products. None of the above mentioned chemicals naturally occur in the soil.

Several tentatively identified volatile compounds also were detected at these two samples, and are presented in Appendix C-1. These compounds are commonly related to petroleum products.

The semi-volatiles analysis of sample [005] detected bis(2-ethylhexyl)phthalate at 580 (B)  $\mu\text{g/kg}$  and di-n-butylphthalate at 97 (BJ)  $\mu\text{g/kg}$ . Semi-volatiles analysis of sample [006] identified bis(2-ethylhexyl)phthalate at 380 (BJ)  $\mu\text{g/kg}$ . Bis(2-ethylhexyl)phthalate is commonly used as a plasticizing additive for polyvinyl chloride (PVC) resins. Di-n-butylphthalate is used in plasticizing vinyl acetate emulsion systems, and in cellulose esters. It is also used as an insect repellent. Phthalates are common laboratory contaminants.

Several tentatively identified semi-volatiles compounds also were detected at these two samples, and are presented in Appendix C-1. These compounds are commonly related to solvents and/or petroleum products.

The inorganic (total metals) analysis of sample [005] identified cadmium at 2.0 mg/kg and lead at 321  $\mu\text{g/kg}$ . The total metals analysis of sample [006] detected cadmium at 1.4 mg/kg and lead at 144 mg/kg.

The cadmium concentrations found at these two samples were within the observed range (<1 to 11  $\mu\text{g/mg}$ ) for the background geochemistry of soils in Missouri. The lead concentrations were above the Missouri soil range (10 to 70 mg/kg, Connor and Shacklette 1975), and may be attributed to leaded petroleum products.

#### Frazier Brothers Construction Company

The soil investigation produced two soil samples [007 and 008] at the Frazier Brothers Construction Company (Figures 2.3-1 and 4.1-8). Sample [007] was collected for the volatile organic analysis, and sample [008] was collected for non volatile fractions (semi-volatile and inorganic analysis). Sample results for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic compounds, in Table 4.1-13. The pesticide organics analysis failed to substantiate the presence of any compounds.

The volatile organic analysis of sample [007] identified 2-butanone (methyl ethyl ketone or MEK) at 4 (J)  $\mu\text{g/kg}$ , toluene at 3 (J)  $\mu\text{g/kg}$ , methylene chloride at 6 (B)  $\mu\text{g/kg}$ , and acetone at 52 (B)  $\mu\text{g/kg}$ . Methylene chloride and acetone are common laboratory contaminants. The

compounds were also found in the associated blank and most likely attributed to laboratory contamination. The Frazier Brothers Construction Company operates a shop for automobile and truck repair in the vicinity of this sample location which may explain the detection of solvent compounds in the soil. 2-butanone (methyl ethyl ketone or MEK) is used as a cleaning solvent, and may have been used during parts and/or tools cleaning. Toluene is a compound encountered in petroleum products. None of the above mentioned chemicals naturally occur in the soil.

Three tentatively identified volatile compounds also were detected in these two samples, and are presented in Appendix C-1. These compounds are commonly related to solvents and/or petroleum products.

The semi-volatiles analysis of sample [008] detected bis(2-ethylhexyl)phthalate at 420 (BJ)  $\mu\text{g/kg}$ . Bis(2-ethylhexyl)phthalate is commonly used as a plasticizing additive. This compound also was found in the associated QA/QC blank. Phthalates are common laboratory contaminants.

Several tentatively identified semi-volatile compounds also were detected in these two samples, and are presented in Appendix C-1. These compounds are commonly related to solvents and/or petroleum products.

The inorganic (total metals) analysis of sample [005] identified cadmium at 6.4  $\mu\text{g/kg}$  and lead at 22.0  $\mu\text{g/kg}$ . Cadmium and lead concentrations found at this sample location were within the observed range for the background geochemistry of soils in Missouri, <1 to 11  $\mu\text{g/kg}$  and 10 to 70  $\mu\text{g/kg}$ , respectively (Connor and Shacklette 1975).

#### QA/QC Background Soil Sample

The soil investigation produced one background soil sample [010] at the intersection of Northwood Drive and Stage Coach Drive (Figures 2.3-1 and 4.1-6). Sample results for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic compounds, in Table 4.1-13. The pesticide organics analysis failed to substantiate the presence of any compounds.

The volatile organic analysis identified methylene chloride at 8 (B)  $\mu\text{g/kg}$  and acetone at 26 (B)  $\mu\text{g/kg}$ . Methylene chloride and acetone are common laboratory contaminants. These compounds were also found in the associated blank and most likely attributed to laboratory contamination.

The semi-volatiles analysis detected bis(2-ethylhexyl)phthalate at 440 (B)  $\mu\text{g/kg}$ , di-n-butylphthalate at 140 (BJ)  $\mu\text{g/kg}$ , and benzoic acid at 970 (J) ppb. Benzoic acid is used in plasticizers, manufacture of dyes and pharmaceuticals, and its attribution is unknown at this time. Di-n-butylphthalate is used in plasticizing vinyl acetate emulsion systems, and in cellulose esters. It is also used as an insect repellent. Bis(2-ethylhexyl)phthalate is commonly used as a plasticizing additive. These phthalate compounds also were found in the associated QA/QC blanks and are common laboratory contaminants.

Several tentatively identified semi-volatiles compounds also were detected at this sample, and are presented in Appendix C-1. These compounds are commonly related to solvents and/or petroleum products.

The inorganic (total metals) analysis of sample [005] identified cadmium at 1.4  $\text{mg/kg}$  and lead at 22.3 (B)  $\text{mg/kg}$ . Cadmium and lead concentrations found at this sample location were within the observed range for the background geochemistry of soils in Missouri, <1 to 11  $\text{mg/kg}$  and 10 to 70  $\text{mg/kg}$ , respectively (Connor and Shacklette 1975).

#### QA/QC Field Equipment Rinsate

The soil investigation produced one rinsate water sample [009] as a field equipment rinsate. Sample results for the volatile organic compounds fraction are summarized in Table 4.1-11; for the semi-volatiles organics parameters, in Table 4.1-12; and for the inorganic compounds, in Table 4.1-13. The pesticide organics analysis failed to substantiate the presence of any compounds.

The volatile organic analysis identified chloroform at 18  $\mu\text{g/L}$ , bromodichloromethane at 2 (J)  $\mu\text{g/L}$ , methylene chloride at 12 (B)  $\mu\text{g/L}$ , and acetone at 23 (B)  $\mu\text{g/L}$ . Chloroform and bromodichloromethane detected in the rinsate sample may be due to the deionized chlorinated water.

Methylene chloride and acetone are common laboratory contaminants. These compounds were also found in the associated blank and most likely attributed to laboratory contamination.

The semi-volatiles analysis detected bis(2-ethylhexyl)phthalate at 5 (BJ) µg/l and di-n-butylphthalate at 1 (J) µg/l. Bis(2-ethylhexyl)-phthalate is commonly used as a plasticizing additive, and may be attributed to the plastic container containing the deionized water used during the preparation of the rinsate sample. Di-n-butylphthalate is used in plasticizing vinyl acetate emulsion systems, and in cellulose esters. It is also used as an insect repellent, and also may be attributed to the plastic container. Bis(2-ethylhexyl)phthalate compound also was found in the associated QA/QC blank. Phthalates are common laboratory contaminants.

Three tentatively identified semi-volatiles compounds also were detected in this sample, and are presented in Appendix C-1. These compounds are commonly related to solvents and/or petroleum products.

The inorganic (total metals) analysis identified lead at 1.8 (B) µg/L. Lead also was found in the associated QA/QC blank.

#### 4.2 GROUNDWATER

Between November 12 - 17, 1991, a total of seven groundwater samples, including a duplicate, were collected from existing residential wells within the study area. Each of these samples was analyzed for the following parameters; volatile organics (including methyl tertiary butyl ether [MTBE]), semi-volatiles (BNA's), total metals, dissolved metals, cyanide and pesticides. One well, at the Daugherty residence on North U Drive, was not sampled because access was denied. All other proposed well samples were collected.

##### Volatile Organics (+MTBE)

No significant concentrations of volatile constituents were identified in any of the well samples. Low concentrations of methylene chloride and acetone were detected in each sample, but these constituents were also found in the laboratory blank and were undoubtedly laboratory

contaminants. Small concentrations of chloroform and bromodichloromethane were detected exclusively in the trip blank (-002) and the rinsate samples (-009). Each of these samples were prepared with water which had been stored in plastic containers. In addition, water used for these samples had very likely been chlorinated for drinking purposes.

At least one unknown or tentatively identified compound was found in each samples during the GC-scan of the volatiles fraction. These findings are summarized in Table 4.2-1. Most notable was the tentative identification of hexane in both of the Thompson well samples (-004, -005) and an ethyl methyl benzene (EMB) isomer in the rinsate sample (-009). Hexane concentrations were estimated to be 5 µg/l and 6.5 µg/l in samples -004 and -005, respectively. The EMB isomer was tentatively identified at a concentration of 15 µg/l exclusively in the rinsate sample, the only sample containing water from the Springfield municipal supply. However, as stated earlier, the rinsate sample water was passed through a plastic container, a potential source for this volatile compound. Freon-113 was tentatively identified in sample -005 at an estimated concentration of 7 µg/l. However, the absence of this compound from the duplicate sample (-004), reduces the significance of this finding.

MTBE was not identified in any of the samples.

#### Semi-volatiles (BNA's)

The presence of two semi-volatile compounds, di-n-butylphthalate and bis(2-ethylhexyl)phthalate, was confirmed in each of the seven well samples. Concentrations of these compounds were generally between 2 µg/l and 15 µg/l. An anomalous concentration of 320 µg/l of bis(2-ethylhexyl)phthalate was detected in sample -008, collected from the Holder Jr. well. However, both of these compounds were also detected in the rinsate sample and the laboratory blank. It is, therefore, unlikely that these compounds are actually groundwater contaminants. Rather, they were likely introduced into the sample during collection in the field, or during preparation in the laboratory, or both. Each com-

TABLE 4.2-1

GROUNDWATER SAMPLE RESULTS  
VOLATILE ORGANICS ANALYSIS  
PHASE 1 SAMPLING  
NORTH U DRIVE RI/FS  
NOVEMBER 12 - 17, 1990  
SAMPLE SERIES M32018-G

COMPOUND	DEGRAFFENREID WELL (-001)	TRIP BLANK (-002)	FRANK WELL (-003)	THOMPSON WELL (-004)	THOMPSON WELL (-005)	WISE WELL (-006)	HOLDER JR. WELL (-007)	HOLDER SR. WELL (-008)	RINSATE (-009)
Hexane (*)	-	-	-	5.0(J)	7.0(J)	-	-	-	-
Freon-113 (*)	-	-	-	-	7.0(J)	-	-	-	-
Ethyl Methyl Benzene Isomer (*)	-	-	-	-	-	-	-	-	15(J)
Dimethyl Benzene Isomer (*)	-	-	-	-	-	6.0(BJ)	-	-	-
Total Unknowns (*)	63(BJ)	50(BJ)	15(BJ)	13(BJ)	54(BJ)	27(BJ)	16(BJ)	28(BJ)	22(BJ)

All Concentrations are in  $\mu\text{g}/\text{kg}$  (ppb).

J = Estimated value.

B = Compound identified in laboratory blank.

(\*) = Compound tentatively identified.

(-) = Compound not detected.

pound is a common plasticizer, and is ubiquitous in field and laboratory equipment.

At least one unknown or tentatively identified compound was identified in each sample during the GC scan. These findings are summarized in Table 4.2-2. An estimated 2,039  $\mu\text{g/l}$  of total unknown hydrocarbons were identified in the Holder Jr. well sample. As noted in the field logbook, water from this shallow well was visibly turbid, and had a distinct odor, similar to that of septic wastes. At the time of sampling, it was concluded that a leaking septic tank was probably nearby, thus explaining the presence of the additional, deeper well merely 20 feet away. (The installation of a deeper well may have become necessary to obtain potable water.) The well owner has not been available to verify this theory.

Approximately 248  $\mu\text{g/l}$  of other unknown (non-hydrocarbons) compounds within the semi-volatiles fraction were detected in the rinsate sample. The presence of low concentrations of unknowns (tentatively identified) in this and other samples may be attributed to the pump, the PVC bailers (for the well samples), or the plastic drum used to hold the pump (and water) during collection of the rinsate sample.

#### Total and Dissolved Metals

Table 4.2-3 summarizes the findings of the total and dissolved metals analyses. Several heavy metals were identified at concentrations above their respective Maximum Contaminant Levels (MCLs) or Maximum Contaminant Level Goals (MCLGs). From a regulatory standpoint, MCLs pertain to water which is delivered to any user of a public water system. Considering the proximity of the Fulbright facility, which includes a water reservoir, deep well and natural spring, the discussion of MCLs would be appropriate at this site. The highest concentrations, and most of those exceeding the regulatory levels, were found in the unfiltered, or total metals, analysis. This circumstance suggests that most of the metal compounds are actually adsorbed to sediment particulates in the water.

TABLE 4.2-2

GROUNDWATER SAMPLE RESULTS  
SEMI-VOLATILE ORGANICS ANALYSIS  
PHASE 1 SAMPLING  
NORTH U DRIVE RI/FS  
NOVEMBER 12 - 17, 1990  
SAMPLE SERIES MG2018-G

COMPOUND	DEGRAFFENREID WELL (-001)	FRAKE WELL (-003)	THOMPSON WELL (-004)	THOMPSON WELL (-005)	WISE WELL (-006)	HOLDER JR. WELL (-007)	HOLDER SR. WELL (-008)	RINGSIDE (-009)
Tribromophenol Isomer (*)	-	-	-	12(J)	-	-	-	-
Alkyl Benzene (*)	-	-	-	-	-	-	-	8.0(J)
Unknown Phthalate (*)	-	-	-	-	9.0(J)	-	-	-
Total Unknown Hydrocarbons (*)	120(BJ)	110(BJ)	65(BJ)	59(BJ)	150(BJ)	2,039(J) 120(BJ)	120(BJ)	-
Other Unknowns (*)	-	-	-	-	79(J)	16(J)	30(J) 16(BJ)	248(J) 8.0(BJ)

All Concentrations are in  $\mu\text{g/kg}$  (ppb).

J = Estimated value.

B = Compound identified in laboratory blank.

(\*) = Compound tentatively identified.

(-) = Compound not detected.

TABLE 4.2-3

GROUNDWATER SAMPLE RESULTS  
TOTAL AND DISSOLVED METALS ANALYSIS  
PHASE 1 SAMPLING  
NORTH U DRIVE RI/FS  
NOVEMBER 12 - 17, 1990  
SAMPLE SERIES MG2018-G

COMPOUND	DEGRAFFENREID WELL (-001)	FRAKE WELL (-003)	THOMPSON WELL (-004)	THOMPSON WELL (-005)	WISE WELL (-006)	HOLDER JR. WELL (-007)	HOLDER SR. WELL (-008)	RINSATE (-009)
Antimony	-	-	-	-	-	68.2/-	-	-
Arsenic	-	-	12.5/6.3(B)	12.6/5.1(B)	-	1.2(B)/-	6.1(B)/-	-
Barium (1)	80.2(B)/ 78.6(B)	46.1(B)/ 42.9(B)	124(B)/ 163(B)	133(B)/ 156(B)	57.6(B)/ 52.6(B)	148(B)/ 99.7(B)	74.1(B)/ 44.4(B)	64.7(B)/ 61.1(B)
Cadmium	-	-	6.1/-	7.7/-	-	11.0/-	-	-
Chromium	-	-	-	-	-	6.8 (B)/-	10.4/-	-
Lead	-	7.4/-	50.5/-	62.5/-	9.4/2.6(B)	178/2.0(B)	76.5/8.7	-/2.5(B)
Mercury	-	-	-	-	-	0.77/NA	0.20/-	-
Nickel	-	-	-	11.2(B)/-	-	33.0(B)/-	12.2 (B)/-	-
Zinc	20.0/15.9(B)	147/107	1,140/513	1,290/596	80.5/63.3	1,580/83.4	382/31.4	27.5/26.2

All Concentrations appear as Total Fraction/Dissolved Fraction and are given in µg/kg (ppb).

B = Concentration is less than the Contract Required Detection Limit (CRDL), but greater than or equal to the Instrument Detection Limit (IDL).

(1) = Laboratory experienced difficulty in maintaining Ba calibration. All Ba concentrations should be considered estimates.

NA = Mercury sample for the dissolved fraction of sample -007 was consumed prior to analysis. No results are available.

(-) = Compound not detected.

However, the two Thompson well samples, -004 and -005, were found to have 6.3 µg/l and 5.1 µg/l, respectively, of arsenic in the dissolved metals fraction. Although there is currently no final MCL for this Class A carcinogen, an MCLG of zero has been proposed. Additionally, these two samples contained cadmium (average of 6.90 µg/l) and lead (average of 56.6 µg/l) in the total fraction of levels well above the proposed MCL of 5 µg/l for each of these metals. The Thompson well samples also contained anomalously high concentrations of zinc in both the total fraction (average of 1,215 µg/l) and dissolved fraction (average of 555 µg/l). Those concentrations of zinc do not pose a health hazard, but they may be related to the high concentrations of the other metals. The unfiltered water from this well was fairly clear and relatively free of sediment.

The Holder Jr. well (-007), which exhibited the most turbid water and was found to contain several unknown hydrocarbons, also contained the highest concentrations of antimony (86.2 µg/l), barium (148 µg/l), cadmium (11.0 µg/l), lead (178 µg/l), mercury (0.77 µg/l), nickel (33.0 µg/l) and zinc (1,580 µg/l), all within the total fraction. The great disparity between the total and dissolved concentrations for any particular metal (for example 1,580 µg/l versus 83.4 µg/l for zinc) in this well is attributable to the high particulate content in the water. It should be noted, though, that the MCLs for cadmium and lead were exceeded in this sample. In addition, antimony, which was not detected in any other well, was detected at a concentration far above its respective Drinking Water Equivalent Level (DWEL). The DWEL is a lifetime exposure concentration that is protective of adverse, non-cancer health effects. The DWEL is not restricted to sources of public water supplies.

The Holder Sr. well (-008) contained the highest concentration of dissolved lead (8.7 µg/l). This much lead in the aqueous phase would essentially render the water undrinkable without further treatment.

#### Cyanide

No cyanide was detected in any of the samples.

### Pesticides

No pesticides were detected in any of the samples. A pesticide analysis was not performed on sample -009 (the rinsate) due to breakage of the sample container during shipment.

Results of the Phase 1 groundwater sampling do not indicate that the primary contaminants associated with this site (BTEX compounds and MTBE) have extended their presence within the study area. In fact, no volatile compounds were conclusively identified in any of the wells.

However, concentrations of hexane and Freon-113 were tentatively identified in the Thompson well, the only well known to be cased through the North View Shale. This is also the only well of those sampled during Phase 1 to have ever exhibited volatile organic contamination in the past. Hexane, though not one of the primary contaminants at this site, had been tentatively identified in a sample of petroleum product collected from the well at the former Curtis service station in 1985.

Well samples were analyzed for analytical parameters other than VOAs. It was anticipated that a more complete characterization of the groundwater chemistry might provide additional clues or concerns regarding the source(s) or impacts of contamination.

Within the semi-volatiles fraction, several unknown hydrocarbons were tentatively identified. For the most part, the occurrences of these compounds are attributable to laboratory contamination. However, the presence of unknown hydrocarbons in one of the wells appears to be the result of localized groundwater contamination. A sample from Holder Jr. well, located at 4064 Northwood Drive, contained an estimated 2,039  $\mu\text{g/l}$  of tentatively identified, unknown hydrocarbons. The water bailed from this well was extremely turbid and had, at times, a distinctive sewage-like odor. Although the water appears unsanitary, it is more likely that this problem is associated with a nearby leaking septic tank rather than the contamination under investigation in this study. This well is believed to be open only to the shallow aquifer.

The well samples were also analyzed for total and dissolved metals. The Thompson well sample had relatively high levels of arsenic, cadmium, lead, and zinc in the total fraction. More importantly, relatively high

levels of arsenic and zinc were identified in the dissolved fraction, indicating that at least those two metals are present in the aqueous phase. The Holder Sr. well, located approximately 200 feet north of the Thompson well, was found to contain a high level of dissolved lead. No organic contamination was ever identified in this well. However, both lead and arsenic are commonly present in many petroleum products. Both metals also have specific gravities much greater than 1.0, and their presence in deeper wells (which both Thompson's and Holder Sr.'s are) is not surprising if it is indeed related to the organic contamination at this site. Another possible source for this inorganic contamination is the landfill in the nearby Mobile Gardens Trailer Park sinkhole.

One additional conclusion may be derived from the groundwater sampling data. It would appear that the groundwater quality in general improves moving north and northeast away from North U Drive proper. The Degraffenreid well, in the shallow aquifer, and the Frake well, upon to both aquifers, consistently showed the fewest number of conclusively or tentatively identified compounds in each of the analytical fractions. The value of this deduction is obviously limited, considering the small number of wells which were sampled. However, the general implication is that water quality in the direction of the Fulbright Pump Station (and reservoir) is inferior. This observation may be worth consideration during future work in the study area.

Note: On December 10, 1990, a sample was collected from the purge water holding tank, located at the former sewage treatment facility (see Section 2.5). The sample was determined to be free of contamination and on December 21, 1990 E & E received permission from Ed Sears, MDNR Water Pollution Control Unit, and Bob Schaefer, Springfield Public Work, to release the water to the nearest sanitary sewer.

## 5. SUMMARY AND CONCLUSIONS

### 5.1 SUMMARY

The following is a synopsis of each potential source, based upon the results of the soil sampling, soil-gas sampling, subsurface source investigations and relevant historical data.

Soil-Gas data are presented in nanograms per milliliter (ng/mL) of air [approximately equal to parts per million (ppm)]. For simplification, the ppm unit is used in this summary section.

#### Degraffenreid Sinkhole

The soil-gas investigation produced six soil-gas samples; and identified traces of benzene and toluene.

The soil investigation produced two soil samples. Compounds identified were carbon disulfide (up to 68 µg/kg), 2-butanone (MEK) at 10 (J) µg/kg, up to 5 (J) µg/kg of toluene, ethylbenzene at 2 (J) µg/kg, total xylene at 11 µg/kg; cadmium (up to 2.0 mg/kg), and lead (up to 321 mg/kg).

#### Frazier Brothers Construction Company

The soil-gas investigation produced 10 soil-gas samples; identified were benzene (<1 ppm), TCE (up to 1 (J) ppm), and traces of toluene.

The soil investigation produced two soil samples; identified compounds were 2-butanone (MEK) at 5 (J) µg/kg, toluene at 3 (J) µg/kg; cadmium at 6.4 mg/kg and lead at 22.0 mg/kg.

### Coble Sinkhole

Geophysical reconnaissance of the shallow subsurface did not identify any burials within the eye of the sinkhole. Two very small anomalies were identified upon the western flank of the sinkhole, but these are believed to be related to an old storage shed which once stood in that general area. Soil-gas samples were collected immediately down-gradient from the anomalies.

The soil-gas investigation produced five soil-gas samples. External radio source interference prevented the detection of any individual target compound at concentrations below 10 ng/mL (ppm). None were identified.

The soil investigation produced one soil sample. Compounds identified were tetrachloroethene (PCE) at 140 µg/kg, pyrene at 120 (J) µg/kg, di-n-butylphthalate at 51 (J) µg/kg, fluoranthene at 120 (J) µg/kg, butylbenzylphthalate at 86 (J) µg/kg, chrysene at 120 (J) µg/kg, benzo-(b)fluoranthene at 110 (J) µg/kg; cadmium at 3.1 mg/kg and lead at 28.8 mg/kg.

### Mobile Gardens Trailer Park Sinkhole

A geophysical reconnaissance of this area indicated that considerable dumping has occurred here, probably over a long period of time. The sinkhole has been filled nearly to natural grade, suggesting the depth of debris may be as much as 20 feet or more. This site is essentially a landfill, thus limiting substantially the value of any surface geophysical data collected within its borders. However, a few discrete, shallow burials containing metallic material were identified during the reconnaissance. These areas were flagged for soil-gas sampling.

The soil-gas investigation produced six soil-gas samples and detected toluene up to 4 ppm (at the vicinity of a geophysics anomaly), and ethylbenzene (up to 1 ppm) in the area surrounding a geophysics anomaly.

The soil investigation produced one soil sample; detected were phenanthrene at 62 (J) µg/kg, pyrene at 200 (J) µg/kg, fluoranthene at 200 (J) µg/kg, butylbenzylphthalate at 82 (J) µg/kg, chrysene at 100 (J)

µg/kg, benzo(b)fluoranthene at 180 (J) µg/kg, benzo(a)anthracene at 94 (J) µg/kg, benzo(a)pyrene at 91 (J) µg/kg, indeno(1,2,3-cd)pyrene at 56 (J) µg/kg; cadmium at 2.4 mg/kg and lead at 21.6 mg/kg.

#### Former Five Gables Service Station

A significant anomaly was identified on this property during the initial geophysical reconnaissance. The anomaly was located in an area which used to contain above-ground gasoline storage tanks and it was decided to grid this area to acquire better resolution. The anomaly, although probably not a tank, is about four or five feet deep and many be related to the former gasoline pumping system. A soil-gas sample was collected near this burial. The soil-gas investigation produced seven soil-gas samples and identified benzene (1 ppm), TCE (up to 9 (J) ppm), and toluene (up to 2 ppm).

#### Former Derby Service Station

This entire site was subject to a grid survey, due to the numerous geophysical anomalies identified during the reconnaissance phase. The most significant was of sufficient proportions to possibly represent a buried tank and was identified beneath a concrete pad in front of (northeast of) the former service station building. Unfortunately, the concrete pad contains re-bar and the conductivity and magnetic data collected over this pad were affected to varying degrees. A vent pipe is still standing in the northwest portion of this property, however, lending support to the theory that the anomaly does represent a tank.

The soil-gas investigation produced six soil-gas samples. The following compounds were identified at trace concentrations: benzene, toluene, xylene, and ethylbenzene. All were detected in the areas surrounding geophysical anomalies.

#### Former Curtis Service Station

Based upon the documented history of contamination over the entire study area, this property was a focal point for subsurface investigation. Accordingly, the entire property was gridded, with the greatest

data density in the northwest corner of the lot, where the former station was actually located. Despite interferences from utility lines and surface obstacles in this northwest corner, at least one significant, unexplained anomaly was identified there with the EM-31. However, the anomaly was not largely supported by the magnetometer data, indicating the object(s) may not have a significant mass. In addition, fairly congruent conductivity and magnetic anomalies were identified near an old well near the center of the site. This well had previously been contaminated with up to one foot of petroleum product. The anomalies were distinguishable from the high magnetic field gradient caused by the well casing itself. Smaller unexplained anomalies were identified in other portions of the site.

The soil-gas investigation produced 14 soil-gas samples. Early unidentified peaks were detected at <10 ng/mL (as benzene). An external radio source interference prevented detection of any individual target compound at a concentration below 10 ng/mL.

#### Montgomery Metal Craft Tank Yard

The soil-gas investigation produced 16 soil-gas samples; detected were benzene (up to 6 ppm), TCE (up to 1120 (J) ppm), toluene (up to 200 ppm), and PCE (up to 1 ppm).

The soil investigation produced one soil sample; detected were tetrachloroethene (PCE) at 34 µg/kg, total xylene at 10 (J) µg/kg; naphthalene at 840 µg/kg, 2-methylnaphthalene at 1500 µg/kg; cadmium at 1.7 mg/kg, and lead at 37.6 mg/kg.

#### Montgomery Metal Craft Plant

The soil-gas investigation produced eight soil-gas samples; identified were benzene (up to 6 ppm), TCE (up to 14 ppm), toluene (<1 ppm), and traces of xylene.

The soil investigation produced one soil sample. Compounds identified were carbon disulfide at 7 (J) µg/kg, 2-butanone at 34 (J) µg/kg, 1,1,1-trichloroethane (TCA) at 9 (J) µg/kg, tetrachloroethene (PCE) at 5 (J) µg/kg, toluene at 1 (J) µg/kg, ethylbenzene at 37 (J) µg/kg, total

xylene at 16 (J)  $\mu\text{g/kg}$ ; naphthalene at 1700 (J)  $\mu\text{g/kg}$ , 2-methylnaphthalene at 4400  $\mu\text{g/kg}$ , fluorene at 440 (J)  $\mu\text{g/kg}$ , phenanthrene at 1100 (J)  $\mu\text{g/kg}$ , pyrene at 420 (J)  $\mu\text{g/kg}$ ; cadmium at 3.7  $\text{mg/kg}$ , and lead at 118  $\text{mg/kg}$ .

#### Parrish Drive and Stage Coach Drive

The soil-gas investigation produced 9 soil-gas samples along Parrish Drive and Stage Coach Drive and did not identify any target compounds.

#### Background Soil Sample

The soil investigation produced one background soil sample at the intersection of Northwood Drive and Stage Coach Drive; identified were benzoic acid at 979 (J)  $\text{mg/kg}$ ; cadmium at 1.4  $\text{mg/kg}$ , and lead at 22.3 (B)  $\text{mg/kg}$ .

#### Field Equipment Rinsate

The soil investigation produced one rinsate water sample as field equipment rinsate; identified were chloroform at 18  $\mu\text{g/L}$ , bromodichloromethane at 2 (J)  $\mu\text{g/L}$ , bis(2-ethylhexyl)phthalate at 5 (BJ)  $\mu\text{g/L}$ , and di-n-butylphthalate at 1 (J)  $\mu\text{g/L}$ . Bromodichloromethane and chloroform may be due to the deionized water chlorination process. Bis(2-ethylhexyl)phthalate may be attributed to laboratory contamination.

#### Geology and Groundwater Investigations

A geologic investigation, aided by resistivity and seismic refraction data collected in and around the study area, identified distinct trends in the local bedrock topography. The investigation also identified potential natural conduits for contaminant migration beneath the study area. A VLF survey, intended to support the objectives of the geologic investigation (specifically, the identification of subsurface migration routes), was also performed at selected sites. No subsurface water catchments were identified with the VLF data, presumably because the water table was below the investigation depth of this method. The

resistivity data suggests that significant open and sediment-filled fractures do exist within the same approximate depth range covered by the VLF survey (approximately 50 feet). Had these porous zones been filled with water, they would have produced rather significant conductive anomalies which should have been identified by the VLF technique.

As expected, the bedrock topography was determined to be highly erratic (typical of pinnacle weathering), and it should be noted that the resolution of the bedrock map is somewhat limited in that it was not feasible to map every knob and furrow. However, general trends were identified and confirmed by three different geophysical techniques; resistivity, seismic refraction, and gamma-gamma geophysical logs. (The downhole logging was performed by MDNR/DGLS in 1985). Of greatest interest, perhaps, was the confirmation of a distinct bedrock low in the general area of the former Curtis service station, between North U and South U Drives. To date, this is where the most significant contamination has been found, and the contaminant source(s) may likely be contained somewhere within the projected boundaries of this bedrock depression.

With respect to additional geologic characterization, the resistivity data identified several anomalous zones which may be potential catchments for contaminants. Some of these zones appear to be sediment filled while others appear to be cavernous. Together, these zones appear to have an approximate northwest-southeast strike, which may reflect a direction of preferential migration for fluids. An additional fracture trend might also be expected to strike at a perpendicular orientation (northeast-southwest). Though this additional trend was not confirmed by the geophysical data, a line of sinkholes within the study area does follow this orientation.

Water level measurements collected during Phase 1 indicate that the potentiometric surface of the deep (Ozark) aquifer has dropped significantly beneath the study area since 1985. Increased pumping of this aquifer can be attributed to relatively dry climate over the last five years and the steady increase in water demands. In addition recharge of this aquifer may have been retarded in the study area by the plugging of

over 60 wells, most of which provided a point of connection between the two aquifers.

Another point of hydrogeologic interest is the identification of an apparent fault (or other groundwater barrier) in the eastern portion of the study area. The elevation of the deep aquifer appears to drop over 125 feet, moving east to west, between two wells located approximately 1,000 feet apart.

No volatile organic or semi-volatile organic compounds were conclusively identified in the well samples collected during Phase 1. However, hexane and freon-113 were tentatively identified, at low concentrations, in the Thompson well, which draws from the lower aquifer. The presence of these compounds may be related to the contamination problem that is the subject of this investigation; hexane has been identified previously, in a sample of petroleum product which was taken from a well at the former Curtis service station.

Several unknown hydrocarbons were tentatively identified in several samples, though generally at low concentrations. In most cases these compounds were also identified in the laboratory blank. However, the Holder Jr. well, located east of Northwood Drive, contained 2,039  $\mu\text{g}/\text{kg}$  of hydrocarbons that were not identified in blank samples. The water quality in this well was visibly poor, and the purge water had a distinct sewage-like odor. This contamination has been tentatively attributed to the possibility that a leaking septic tank is located near the well. The well owner has not been available to confirm this theory.

The Thompson well samples contained relatively high levels of arsenic, cadmium, lead, and zinc. Two of these metals, arsenic and zinc, were found at elevated levels in the aqueous (dissolved) phase. The Holder Sr. well, located just north of the Thompson well, was found to contain an elevated concentration of dissolved lead. The exact concentration was 8.7  $\mu\text{g}/\text{l}$ , above the proposed MCL of 5  $\mu\text{g}/\text{l}$  for this metal. Both arsenic and lead are commonly present in many petroleum products. Further, they were identified in wells (Thompson and Holder Sr.) located within 200 feet of each other and which are both open to the deep aquifer (The Holder Sr. well is actually open to both aquifers).

Considering these compounds have specific gravities much greater than 1.0, their presence in the deeper aquifer is not surprising if it is indeed related to the organic contamination at this site.

Lastly, there is a general implication that water quality in the direction of the Fulbright Pump Station, that is, northeast from the center of the study area, is inferior. To the extreme north and northwest, wells within the study area consistently showed fewer compounds within each of the analytical fractions. However, the small number of wells sampled, and the limits of the study area, should confirm this observation to be only an implied general condition.

## 5.2 CONCLUSIONS AND RECOMMENDATIONS

As described in Section 1, the objectives of Phase 1 of the Remedial Investigation were to:

1. Identify chemicals present and the affected media;
2. Identify apparent sources of contamination, and;
3. Predict contaminant migration pathways

This section discusses conclusions within the framework of the above objectives. The conclusions and recommendations are based both on the data collected in the Phase 1 investigation, and on historical data. Based upon this information, the original nine potential source properties have been classified according to their weight as potential sources of groundwater contamination. Three of the properties can be dismissed as very unlikely sources without further characterization; these will be discussed first. Three of the properties, although not the likeliest sources, will require limited additional characterization; these will be discussed second. The three remaining sites are the most probable sources of groundwater contamination but will require additional investigation to confirm attribution; these will be discussed last.

Contaminants associated with the sites are mentioned here qualitatively, to support the recommendations; details of the analytical re-

sults are provided in the text. Lastly, conclusions of the likely contaminant migration pathways are discussed, within the limitations of the data gathered thus far. Recommendations presented should be considered preliminary in nature pending consultation with the MDNR Waste Management Program, (WMP) and Division of Geology and Land Survey (DGLS).

## **No Further Action Under Phase 2**

### **Degraffenreid Sinkhole**

Although limited volatile organic compounds were found in the soil gas survey and in the soil samples, the well on this property remains uncontaminated. Also, several uncontaminated wells exist between this site and the inferred plume. In addition, based on the limited potentiometric data for the shallow aquifer, the Degraffenreid sinkhole appears to be downgradient with respect to North U Drive and the inferred plume. While it is unlikely that this site is responsible for or contributing to the groundwater pollution at North U Drive, the potential exists that contaminants could migrate from the inferred plume. It is recommended that no further work be initiated here under Phase 2 of this investigation. However, because of the limited surficial compounds detected, MDNR may consider investigation of this site as a separate problem with a lower priority.

### **Former Five Gables Service Station**

The soil gas survey at this site found TCE, toluene, and traces of benzene. However, a nearby well was not contaminated and the historical data indicates this site is probably downgradient from the inferred contaminant plume. No apparent source of contamination was found at this site and it is, therefore, recommended that no further work be performed under Phase 2.

### **Former Derby Service Station**

This site appears to contain an underground storage tank. This was suggested by the geophysical data and further verified by the existence of a vent pipe adjacent to the razed building foundation. In addition,

BTEX compounds were found in the soil-gas samples, indicating a possible leak. At least one well (plugged) exists, between this site and the inferred contaminant plume, where contamination was never detected in the past sampling. It is recommended that no further work be done at this site under Phase 2 of this investigation. However, this site may be considered for investigation under the states Underground Storage Tank (UST) Program.

#### Limited Work Under Phase 2

##### Frazier Brothers Construction Company

Volatile organic compounds were found in the soil gas and in the soil samples at this site. Some volatile organic compounds would be expected in the soil since this is an active facility, with a number of vehicles and a vehicle maintenance garage. The nearby well was not contaminated with volatile organic compounds, which suggests that this site is not responsible for, or contributing to, the groundwater contamination. To confirm this belief it is recommended that one soil boring be drilled to the top of bedrock and soil samples be obtained for analysis of volatile organic compounds.

##### Coble Sinkhole

Several semi-volatile compounds and one volatile compound (PCE) were found in a soil sample collected within the boundaries of this sinkhole. Since only PCE was identified, and the historical data suggests that the contaminant plume is actually moving towards this feature, it is unlikely that this site is responsible for or contributing to the groundwater contamination. It is recommended that this be confirmed by drilling one soil boring and obtaining samples for volatile organic analysis.

##### Mobile Gardens Trailer Park Sinkhole

Semi-volatile organic compounds were found in the soil sample and benzene was found in the soil gas. Only benzene was found in the soil sample collected at this site. Also, the historical data indicates that

the plume is moving toward this sink. Since this site is essentially a landfill, many different organic and inorganic compounds may be migrating into the vadose zone. (Relatively high levels of dissolved lead, arsenic, and zinc were identified in two wells immediately northwest of the sinkhole). The potential exists that this site may be contributing to the groundwater contamination. However, because of the anticipated groundwater flow direction it is probably not the primary source for the original contaminant plume. It is recommended that a soil boring be drilled during Phase 2 to determine whether the contamination detected extends to the top of rock. Samples would be analyzed for volatile organic compounds, and possibly metals.

#### **Primary Potential Sources Under Phase 2**

##### **Former Curtis Service Station**

Although the soil gas survey did not find significant contamination (possibly due to radio interferences), the historical data indicates a well (plugged) at this site was by far the most contaminated. When this well was sampled, one foot of "product" was found floating on top of the groundwater. During the same sampling effort, another well some 120 feet away was contaminated, but did not have floating product. This suggests that the well containing product may have been contaminated by a nearby point source such as a tank, or that contaminants were poured directly into the well (the latter scenario may explain the absence of soil-gas contamination). Since chlorinated organic compounds were found in this well, it is likely that an underground petroleum storage tank, while possibly contributing to the plume, was not the sole source of contamination.

The first report of well contamination was from a property owner adjacent to this site; subsequent reports of well contamination came from residences to the east and later to the north of this site. As will be described later, there also appears to be a joint/fracture system within the study area which has allowed contamination to migrate along controlled pathways away from this particular property. Despite the lack of soil-gas contamination, these additional circumstances

indicate that this property is a legitimate potential source. Further study of this site is warranted, and should include borings, a monitoring well and possibly a test pit(s) to identify suspicious geophysical anomalies near the well, and near the former service station building.

#### Montgomery Metal Craft Tank Yard

Soil gas and soil samples identified several volatile organic compounds at this site. This site is also located near the area where initial well contamination was reported. Any contamination originating at this property would likely be susceptible to migration via the joint/fracture system briefly mentioned above. Because of these findings this site may also be a potential responsible party (PRP) to the groundwater plume. It is recommended that additional study of this site include borings and subsurface soil sampling.

#### Montgomery Metal Craft Plant

Volatile organic compounds were found in the soil gas and in the soil samples. Past tank cleaning and coating practices may be the primary source of this surficial contamination. However, this site also lies within the area of initial groundwater contamination and further work will be necessary to determine the vertical extent of the surface contamination. It is recommended that additional work include borings and subsurface soil sampling.

#### Identification of Chemicals Present

Soil gas and soil sample analysis indicate the original primary contaminants, benzene, toluene, ethylbenzene, and xylene, remain of concern. While other contaminants were detected, these are most likely either confined near the surface (and associated with surface spills), or simply secondary compounds associated with the BTEX contamination. Results for the well samples collected in Phase 1 indicate no significant groundwater contamination has spread as far as Parrish Drive (north of the primary potential sources). However, because of the limited number of wells sampled, it is recommended that future

groundwater samples collected under Phase 2 (via monitoring wells) have a full priority pollutant analysis performed.

#### **Preliminary Contaminant Migration Pathway**

It can be interpreted from the Phase 1 investigation that the extent of contaminant migration has not changed drastically since previous studies. However, by eliminating some of the previous potential source areas, the conceptual geological model explaining migration from the remaining primary potential sources can be enhanced.

The following is a list of key elements which can be used to formulate a more comprehensive migration model and would be utilized to develop the Phase 2 Work Plan:

- o Groundwater contamination most likely originated in the vicinity of North U and South U Drives, on either side of Old Missouri Highway 13;
- o Groundwater contamination may be a combination of infiltration of past surface spillage at the Montgomery Metal Craft properties, and leakage/spillage near or into the well at the former Curtis service station (additional work is recommended at these sites);
- o Sinkhole development in and around the study area has evolved in an orientation parallel to the regional joint/fracture pattern (that is northeast/southwest and northwest/southeast directions);
- o While a more direct route of contamination to the groundwater exists at the sinkholes, soil gas and soil samples indicate these are not the likely routes by which the contaminants entered the subsurface;
- o Upon reaching the groundwater, contaminants from the three primary potential source areas would migrate along northeast and northwest trending joint patterns;
- o Contamination has not occurred downgradient from the inferred plume (the boundaries of this plume were estimated prior to Phase 1 sampling);

- o Limited water level information indicates that flow within the shallow aquifer is to the northeast, at least within the northern half of the study area;
- o Hydrogeologic data obtained during Phase 1 indicates that water levels in the deep aquifer, beneath the study area, have dropped significantly in recent years. Vertical migration of contaminants may have been extended as a result of this phenomenon;
- o Contaminant migration may be facilitated or impeded by deeper structural features within or near the study area.

It is anticipated that actual contaminant attribution to the groundwater can be defined by implementing the recommendations outlined for each site. Further characterization will depend upon a hydrogeologic study that should include monitoring wells, completed in both the shallow and deep aquifers, pump or slug tests, and dye tracing. Utilizing the geophysical and limited hydrogeologic information obtained during Phase 1, and the historical information obtained prior to Phase 1 field activities, well locations can be chosen to intercept the most likely migration routes leading from the general area of the suspected sources.

The well data obtained during Phase 1 was limited exclusively to areas north of the suspected source properties. Consequently, there are significant data gaps to the east, west, and south of the source area, particularly to the west and south. Although both of these latter orientations are believed to be essentially upgradient, with respect to groundwater flow in both aquifers, some characterization in these direction will be necessary if for no other reason than to confirm the potentiometric gradients and bound the extent of groundwater contamination. The number and location of monitoring wells, and other specifics concerning recommended Phase 2 work, will be finalized after consultation with the MDNR WMP and DGLS.

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